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BIOLOGICAL ASSESSMENTS OF THE HAWAII BOTTOM FISH STOCKS AND THE SOUTHEAST HANCOCK SEAMOUNT ARMORHEAD STOCK, 1988

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ABSTRACT

The Hawaiian bottom fish resource comprises 10 major species, including 7 snappers, 2 groupers, and 2 jacks. Opakapaka, Pristipomoides filamentosus, is the most important species and accounted for 29% of the estimated total catch in 1988. Next in importance are uku, Aprion virescens (28%), onaga, Etelis coruscans (14%), and hapuupuu, Epinephelus quernus (11%). Several major changes in the species composition of the catch occurred in 1988. In the main Hawaiian Islands (MHI), the catch of uku increased to 10 times the 1987 catch, and the catch of opakapaka increased to almost twice the 1987 catch. In the Northwestern Hawaiian Islands (NWHI), the catch of opakapaka decreased to almost half the 1987 catch.

In the NWHI, total catch of all species combined and of opakapaka alone declined in 1988 after reaching record highs in 1987. These decreases were precipitated by decreases in catch per trip and total number of trips. An additional change in the NWHI fishery was that effort became more equally distributed among various islands of the NWHI, suggesting that most of the localized opakapaka "hot-spots" have been found and the fishing-up phase of the NWHI fishery is nearing its end.

The biological assessment of the stocks was based on weight-frequency data collected at the wholesale markets in Honolulu. For nearly all species, the size of the fish caught in the NWHI was considerably larger than in the MHI. Although this indicates that the past fishing pressure was greater in the MHI, it is not possible to use this information to quantitatively assess whether the fishing effort is excessive either in the sense of growth overfishing or recruitment overfishing. However, in the MHI the apparent fishing rates are high, and the sizes at entry to the fishery are below the size at maturity for opakapaka, onaga, ehu, and white ulua, suggesting that the reproductive population could be low enough to jeopardize future recruitment.

The biological assessment of the the armorhead, Pseudopentaceros wheeleri, stock on the Southeast Hancock Seamount was based on information obtained on research cruises conducted by the Southwest Fisheries Center Honolulu Laboratory (SWFC HL). Based on the CPUE obtained with bottom longlines, the abundance of armorhead increased in 1988 over its record low in 1987. Over the 4 years of the stock assessment program, however, the armorhead population has not shown the sustained increase anticipated as the result of the current fishing moratorium. Because the armorhead on Southeast Hancock Seamount probably do not comprise a discrete breeding population, and instead, form a small part of a much larger population, we believe the protection provided by the moratorium is insufficient to rebuild the stock and some form of international management of the fisheries on all of the Emperor-Hawaiian Ridge seamounts is needed.

INTRODUCTION

In 1986, a fishery management plan (FMP) was implemented by the Western Pacific Regional Fishery Management Council (Council) for the bottom fish stocks in Hawaii, American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands and for the groundfish stock on the Hancock Seamounts (Council 1986). One provision of this FMP is that every year a plan monitoring team, whose members are appointed by the Council, will prepare an annual report summarizing its assessment of the biological condition of the stocks and economic condition of the fisheries. In addition to their inclusion into the annual report, the previous biological assessments of Hawaii's bottom fish stocks (Ralston and Kawamoto 1987, 1988) and the seamount stocks (Somerton 1988) were reported in separate documents to allow greater detail than in the annual report. The present document continues this precedent, but for the first time, the assessments for the bottom fish and the seamount stocks are combined.

The biological characteristics of the bottom fish and seamount stocks and the nature and current status of their associated fisheries differ considerably. Hawaii's bottom fish stock comprises a taxonomically diverse group of fishes whose primary members are snappers, groupers, and jacks (Table 1). This stock supports a commercial hook-and-line fishery throughout all of the Hawaiian Islands and additionally supports a large sport fishery in the main Islands. Most of the commercial catch is landed whole at the central wholesale market, in Honolulu, where it is monitored by personnel from the SWFC HL, National Marine Fisheries Service, NOAA to obtain information on the number and size distribution of each species. Essentially the entire stock assessment of bottom fish is based on this auction sampling. By comparison, the seamount stock nearly comprises a single species, pelagic armorhead, *Pseudopentaceros wheeleri*, and once supported a large foreign trawl fishery. The stock apparently could not sustain the fishery, and between 1972 and 1978, catch per unit effort (CPUE) plummeted to <1% of its initial level (Somerton 1988). Thus, the FMP included a moratorium on all groundfishing activities within the U.S. Exclusive Economic Zone surrounding the Hancock Seamounts. Since this moratorium precluded the use of fisheries data for stock assessment, the Honolulu Laboratory initiated a program of routine sampling cruises to the Southeast Hancock Seamount. Stock assessment of armorhead is based entirely on data collected on these cruises.

BOTTOM FISH

Methods

Approximately 50% of the Hawaiian commercial catch of bottom fish is sampled at a centralized wholesale fish market in Honolulu. The catch of each vessel is sold either as individual fish or, more commonly, in lots. A lot always includes fish of only one species and has been sorted so that all individuals are approximately the same size. Since 1984, information obtained for each lot included the following: species identity, total weight (in pounds), number, vessel identification, location of capture, buyer, price, and date of sale. Although the weight of the individual fish within a lot was not measured, the weight-frequency distribution of the catch can be estimated with approximately 88-99% accuracy from the mean fish weight in each lot (Ralston et al. 1986).

The biological assessments of the bottom fish stocks are based on the shapes of the weight-frequency distributions. Typically, these distributions appear dome-shaped because the number of fish landed increases with individual weight until some maximum (mode) is reached and decreases thereafter. One quantitative measure of the size of the fish harvested, the weight at entry to the fishery ($\underline{w}_c$), was estimated as the average of the minimum and modal weight.

In previous bottom fish assessment reports (Ralston and Kawamoto 1987, 1988), the analysis of the weight-frequency distributions progressed further, and various biological attributes, including growth and mortality rates, were estimated from the data. The accuracy of this type of analysis, however, depends on the validity of a variety of assumptions, especially the assumption that equilibrium conditions prevail within the fishery. After preliminary analysis of the 1988 data, it became clear that at least some of the bottom fish stocks were not in equilibrium and, instead, either showed abrupt changes in size structure or experienced large changes in catch. Since such changes can result in erroneous estimates of the biological attributes, we have chosen to avoid any misinterpretation of the data and simply present the weight-frequency histograms without further analysis. Although this approach does not provide quantitative estimates of the current fishing rates, some qualitative indication of the past fishing rates can be obtained from the shape of the size distribution. In particular, we assumed that a population composed of small fish has experienced greater fishing mortality than a population composed of large individuals of the same species.

In addition to providing some qualitative assessment of the relative fishing mortality experienced by the various stocks, we also consider the possibility of recruitment overfishing or the inadequate preservation of a brood stock. Ideally, we would like to estimate the size of the current spawning population, measured as a fraction of the spawning population prior to fishing, and the minimum size of the spawning population necessary for continued recruitment. Unfortunately, the available data are inadequate to estimate these quantities, and we must provide a more qualitative assessment: If a species appears to be experiencing a relatively high mortality rate and has a $\underline{w}_c$ less than the weight at maturity, then the possibility of recruitment overfishing must be considered. Conversely, if a species appears to be experiencing a low mortality rate and has a $\underline{w}_c$ larger than the weight at maturity, then it is likely that sufficient brood stock is being preserved.

Fishing effort (trips) and CPUE (pounds per trip) were calculated for the NWHI fishery under the assumption that trips must have produced at least a 1,000-lb landing to be considered valid (Ralston and Kawamoto 1987). Since CPUE will vary among vessels, even when they are fishing side-by-side, because of differences in vessel size, fishing method, and previous experience, average CPUE will vary with the composition of the fleet. To avoid this, a time series of CPUE was developed that considered only those vessels having fished every year since 1984.

Results

Hawaii's bottom fish resource comprises 10 principal species, including 7 snappers, 1 grouper, and 2 jacks (Table 1). Opakapaka, Pristipomoides filamentosus, is the mainstay of the commercial fishery, accounting for 29% of the estimated catch in 1988 (Table 2). Next in importance are uku, Aprion virescens (28%), onaga, Etelis coruscans (14%) and hapuupuu, Epinephelus quernus (11%). The fishery for these species is still growing, and the estimated combined catch of all species has increased in each succeeding year between 1984 and 1988. Since the development and characteristics of the fishery in the main Hawaiian Islands (MHI) differed from that in the Northwestern Hawaiian Islands (NWHI), the two areas are considered separately in this report.

Several major changes in the general pattern of bottom fish catches occurred in 1988. First, the catch of uku in the MHI increased by more than 10 times over the 1987 catch (Table 2). Second, the catch of opakapaka increased by almost two times over the 1987 catch in the MHI, but decreased to less than half of the 1987 catch in the NWHI. The catches of hapuupuu and butaguchi, Pseudocaranx dentex, in the NWHI also both decreased in 1988 after several years of steady increase.

Catch and Fishing Effort in the NWHI

Fishing effort, measured as the number of valid trips, declined from 118 trips in 1987 to 83 trips in 1988 (Table 3). This 30% decrease continued the downward trend in effort that was first noticed in 1987. Similarly, the number of vessels participating in the NWHI fishery declined from 26 in 1987 to 14 in 1988, but the average number of trips per vessel increased from 4.5 to 5.9.

Average catch per trip (CPUE) for all vessels declined to 6,000 lb/trip in 1988 after reaching a 4-year high of 7,100 lb/trip in 1987 (Table 3). This trend could be misleading, however, because the composition of the fleet has changed with time. To eliminate any bias, the time trend in CPUE was restricted to the five vessels that fished in every year. The resulting trend (Fig. 1) shows that the average catch per trip, considering either opakapaka alone or all species together, declined somewhat in 1988.

The geographical distribution of the catch among the NWHI has changed substantially since 1984 (Fig. 2). Initially the catch was obtained in the southeastern part of the NWHI, but during 1986-87, the fleet rapidly expanded operations to the northwest. During this expansion, the catch was concentrated at one or more island "hot-spots" that had never been fished before. In 1988, however, the catch was more equally distributed among islands, suggesting that most of the hot-spots had been found. Such an interpretation is consistent with the decline in CPUE observed in 1988.

Status of Individual Species

Opakapaka.--In the MHI, the modal weight of opakapaka in 1988 was 2 lb, exactly the same as it was in 1987, and the overall weight-frequency distribution was essentially the same as it was in the previous 3 years (Fig. 3). In the NWHI, the condition of the opakapaka stock is quite different. The modal weight increased to 11 lb in 1988 from 9 lb in 1987 (Fig. 4), and the overall weight-frequency distribution shows that large fish generally were more prevalent in 1988 than in the preceding 4 years (Fig. 4). We have no explanation for such an abrupt change in the size distribution of NWHI opakapaka after 4 years of relative stability; however, much of the catch was taken at Gardner Pinnacles, an area previously receiving little effort.

Regardless of this anomaly, opakapaka clearly are considerably smaller in the MHI than in the NWHI, indicating that the MHI stock has experienced greater fishing pressure. Although nothing definitive can be said about possible growth overfishing (Ralston and Kawamoto 1987, 1988), we can make some preliminary assessments of possible recruitment overfishing. In the MHI, the weight at entry into the fishery (1.5 lb) is less than the weight at maturity (2.8 lb; Kikkawa 1984), and approximately 57% of the catch (in numbers) is composed of immature fish. This indicates the spawning stock is likely to be small and the continued increase in catch may jeopardize future recruitment. In the NWHI, however, the weight at entry of opakapaka (6.5 lb) is considerably larger than the weight at maturity, and only 1% of the catch (in numbers) is immature. This indicates there is presently little danger of recruitment overfishing.

Onaga.--In the MHI, the modal weight of onaga was 2 lb in 1988, exactly the same as in 1987, and the overall weight-frequency distribution was essentially the same as in the preceding 3 years (Fig. 5). In the NWHI, the modal weight of onaga was 12 lb in 1988, down 2 lb from 1987. However, both the 1987 and 1988 weight-frequency histograms are bimodal, which is unusual, and the decrease in modal weight is likely unrelated to changes in fishing mortality (Fig. 6). This view is supported by the overall weight-frequency distribution in 1988, which included fewer large fish than in 1987 but about the same number as the preceding 2 years. Again, the smaller sizes of onaga in the MHI indicates, the stock has experienced greater fishing pressure than in the NWHI.

In terms of potential recruitment overfishing, the situation is similar to opakapaka. In the MHI, the weight at entry to the fishery (1.5 lb) is much less than the weight at maturity (9.9 lb; Everson et al. in press), and approximately 82% of the catch (in numbers) is composed of immature fish. This suggests that recruitment overfishing is possible, even at the current level of fishing. In the NWHI, the weight at entry (6.5 lb) is less than the size at maturity, and 47% of the catch (in numbers) is immature. Regardless of the sizable catch of immature fish, the likelihood of recruitment overfishing is less in the NWHI than in the MHI, because the fishing pressure experienced by the NWHI stock appears to be less.

Ehu.--In the MHI, the modal weight of ehu in 1988 was 1 lb, the same as it was in 1987, and the overall weight-frequency distribution was essentially the same as in the previous 4 years (Fig. 7). In the NWHI, the modal weight was 3 lb in 1988, the same as in 1987, and the overall weight-frequency distribution was essentially the same as in the preceding 3 years (Fig. 8). As with onaga, the size of ehu in the NWHI is considerably larger than in the MHI, and this difference reflects the difference in fishing pressure between areas.

In terms of potential recruitment overfishing, the situation is also similar to that of onaga. In the MHI, the weight at entry (0.5 lb) is considerably smaller than the weight at maturity (1.6 lb; Everson 1984), and 90% of the catch (in numbers) is composed of immature fish. In the NWHI, the weight at entry (1.5 lb) is nearly equal to the weight at maturity, and 38% of the catch (in numbers) is immature. This indicates recruitment overfishing is possible at the current level of fishing effort in the MHI but unlikely in the NWHI.

Uku.--In the MHI, the modal weight of uku was 6 lb in 1988, exactly the same as in 1987, and the overall weight-frequency distribution was also nearly the same as in 1987 (Fig. 9). The weight-frequency distributions for 1987 and 1988, however, include more smaller fish than in previous years and suggest that a large recruitment of small fish occurred in 1987. It is not clear, however, if the tenfold increase in uku catch from 1987 to 1988 was due to this recruitment or to some change in the availability of uku.

In terms of potential recruitment overfishing, the weight at entry (3.5 lb) is slightly greater than the weight at maturity (3.3 lb; Everson et al. in press), but only 4% of the catch (in numbers) is immature. This indicates that, at present, the likelihood for recruitment overfishing is presently small.

Hapuupuu.--In the MHI, the modal weight of hapuupuu in 1988 was 8 lb, exactly the same as in 1987, and the overall weight-frequency distribution was essentially the same as it was in the preceding 5 years (Fig. 10). In the NWHI, the modal weight of hapuupuu in 1988 was 10 lb, increasing greatly from 4 lb in 1987, and the overall weight-frequency distribution shows that intermediate to large fish were generally more prevalent in the 1988 catch than in the previous 4 years (Fig. 11). This change probably reflects a change in the fishing strategy of the fleet rather than a change in the stock. Catches of hapuupuu are incidental to catches of opakapaka, ehu, and onaga. In recent years, the NWHI catch of opakapaka greatly exceeded the catch of ehu and onaga, but in 1988, the opakapaka catch dropped to less than one-half of its 1987 level and the catches of ehu and onaga both increased in an apparent attempt by fishermen to make up the shortfall. Since ehu and onaga occur in deeper water than opakapaka, such a shift in species composition probably indicates a shift in fishing depth. Since hapuupuu occur in progressively deeper water as they grow (Ralston 1981), a shift in fishing depth would probably result in a shift in the size of hapuupuu that are incidentally caught.

The weight at maturity of hapuupuu is unknown; therefore, at present, we have no indication of the likelihood of recruitment overfishing.

Butaguchi.--In the NWHI, the modal weight of butaguchi was 14 lb in 1988, exactly the same as in 1987, and the overall weight-frequency distribution is similar to that in 1987 (Fig. 12). This apparent stability of the weight-frequency distribution is recent, however; and the distributions have fluctuated widely over the previous 4 years. Like hapuupuu, butaguchi tend to occur in deeper water as they grow (Ralston 1981), and shifts in the size distribution could reflect differences in fishing depth rather than changes in the population. However, unlike hapuupuu, a sizable fraction of the catch is probably obtained with directed fishing effort rather than caught incidental to other species. In the MHI, the fishery for butaguchi is insignificant and has been omitted here.

Like hapuupuu, the weight at maturity of butaguchi is unknown, and no assessment of the likelihood of recruitment overfishing can be made.

White ulua.--In the MHI, the modal weight of ulua was 2 lb in 1988, exactly the same as in 1987, but the overall weight-frequency distribution indicates that there were slightly more fish at intermediate sizes in 1988 than in previous years (Fig. 13). In the NWHI, the modal size was 36 lb in 1988, exactly the same as in 1987, but the overall weight-frequency distribution again indicates that there were substantially more large fish in 1988 than in previous years (Fig. 14). The reasons for the extreme variability in the NWHI size distributions among years is unknown.

In terms of potential recruitment overfishing, the situation is similar to opakapaka, onaga, and ehu. In the MHI, the weight at entry (4.0 lb) is much smaller than the size of maturity (7.0 lb; Sudekum et al. in prep.), and 67%, by numbers, of the catch was immature. In the NWHI, however, the weight at entry (22.0 lb) was much larger than the weight at maturity and 0% of the catch was immature. In the MHI, recruitment overfishing is possible at the current level of fishing effort, but in the NWHI, it is unlikely even with a substantial increase in fishing effort.

Incidental species.--Kalekale, *Pristipomoides sieboldii*; gindai, *P. zonatus*; and lehi, *Aphareus rutilans*, are minor components of the bottom fish catch and are caught incidentally to other species. Because of this, we simply summarized the weight-frequency distributions over 1984-88 in the MHI and the NWHI for the first two species and in the MHI alone for the last. Kalekale and gindai show similar patterns in that the size distribution within each area has remained fairly constant over time, but fish from the NWHI are generally larger than those from the MHI (Fig. 15). Lehi, which are abundant only in the MHI, display considerable variability in size among years, but fish sampled in 1988 are clearly larger than those sampled in preceding years (Fig. 15). The weight at maturity is unknown for all three of these species.

Discussion

The condition of the various stocks differs considerably between the NWHI and the MHI. In the NWHI, there is little to suggest that the fishery is stressed. Opakapaka, the traditional mainstay of the NWHI fishery, is apparently decreasing in abundance, and fishers are compensating for this by spreading their effort more equitably among the islands and by increasing effort directed toward onaga and ehu. Decreases in opakapaka catch and CPUE probably reflect the fishers' decreasing ability to find undiscovered opakapaka hot-spots. Such a pattern is normal during the early stages of a developing fishery and, from a purely biological perspective, should not be viewed with alarm. In terms of reproductive potential, all species examined, except onaga, have a weight at entry larger than the weight at maturity and are therefore unlikely to experience recruitment overfishing unless there are substantial increases in fishing pressure. One caveat, however, is that the estimated weight at entry can be too large if the geographical distribution of the catch is not in equilibrium with the stock, that is, if the catch is concentrated in areas that have received little previous fishing effort. Such disequilibrium has existed in the NWHI since the fishery started, but judging from the recent changes in the geographical distribution of the catch, it appears that equilibrium conditions will soon be achieved.

In the MHI, several stocks are clearly stressed. Although catches of the deeper species (ehu, onaga, and kalekale) declined in 1988, catches of shallow species continued to show an increasing trend (Table 2). Most of these changes, however, do not reflect changes in the conditions of the various stocks but are instead probably related to an apparent change in the fishing pattern of the bottom fish fleet during 1988. For example, in response to the huge increase in uku abundance, fishers may have made more bottom fish fishing trips and shifted effort from deep water to shallower areas inhabited by uku. Since opakapaka is caught incidentally by fishers targeting uku, the large increase in the opakapaka catch was likely due to the increase in uku effort rather than to any change in opakapaka abundance. In terms of reproductive potential, four species (i.e., opakapaka, ehu, onaga, white ulua) are being harvested at such small sizes that the catch is primarily composed of juveniles. This, coupled with the probable, high fishing pressure, suggests that the spawning stock is likely to be quite low, perhaps sufficiently low to influence future recruitment.

In the last bottom fish stock assessment report, Ralston and Kawamoto (1988) recognized the stressed condition of these stocks and suggested increasing the minimum commercial size above the current 1-lb limit as a remedy. In response, the State of Hawaii's Department of Land and Natural Resources proposed that a 3-lb minimum size limit would be appropriate for opakapaka, onaga, and uku. Such a minimum size would be effective only to the extent that undersized fish are no longer killed by the fishery. Since opakapaka and onaga live in relatively deep water, few would survive capture and release; therefore, the success of an increased minimum size limit depends upon the ability of fishers to avoid catching small fish. We are now beginning research on the targetability of small opakapaka and anticipate at least preliminary results in the next stock assessment report.

ARMORHEAD

Methods

Armorhead stock assessment is based on longline catches obtained by SWFC HL personnel during research cruises to the Southeast Hancock Seamount. Eight stock assessment cruises have occurred since 1985; the inclusive dates and the sampling effort, expressed as the number of hooks set, are shown for each cruise in Table 4. The fishing gear and sampling methods are described in Somerton (1988) and Somerton and Kikkawa (in prep.).

Two types of information are obtained from the longline catches: relative abundance (CPUE) and fatness index (FI). A detailed description of the methods used for estimating these two quantities is provided in Somerton and Kikkawa (in prep.), but the major features are as follows. The estimate of CPUE, expressed as the catch per 1,000 hooks, was a depth stratified average corrected for the presence of hook timers (Somerton et al. 1988). Previous estimates of armorhead CPUE (Somerton 1988) were calculated by using four depth strata. In this report, we also use four depth strata, but the depth boundary between the first (shallowest) and second strata was changed to better reflect the distribution of armorhead. Since the change in boundaries changes the estimates of CPUE, all previous estimates were recalculated by using the new boundary definitions. The estimate of FI, calculated as body depth divided by fork length, was used as an index of residence time, that is, the time between sampling and when an armorhead first arrived at the seamount. Because armorhead arrival apparently occurs over relatively short time intervals, frequency histograms of FI tend to display modes representing cohorts of fish. These modes were tracked through the time series of FI frequency distributions to verify patterns of recruitment indicated by changes in CPUE.

In 1988, Honolulu Laboratory personnel conducted an exploratory research cruise that surveyed three of the Emperor Seamounts (Colahan, Kammu, and Koko Seamounts) in addition to the Southeast Hancock Seamount (Table 4). Armorhead were sampled with longlines by using the same techniques as the normal stock assessment cruises, but without the hook timers. Estimates of average CPUE were not stratified by depth because the depth variation on the northern seamounts is imprecisely known.

Results

Armorhead CPUE on Southeast Hancock Seamount fluctuated from a high in August 1986 to a low in August 1987, then increased again in August 1988 (Fig. 16). Since no commercial fishing occurred during this period, the fluctuations apparently were due to episodic recruitment, followed by high natural mortality. The episodic pattern of recruitment can be seen in the time series of FI frequency distributions (Fig. 17). Since fish with a FI's of relative abundance of such fish indicated periods of recruitment. Over the 4-year series, the relative abundance of fat fish increased twice, once between June 1985 and August 1986 and again between August 1987 and August 1988. Both of these periods of recruitment coincided with the periods of rapid increases in CPUE.

Some information on the pattern of recruitment that occurred prior to the stock assessment cruises can be obtained by using the average rate of decrease of FI (0.002 per month) to estimate when a cohort arrived at the seamount. When this technique was applied to the earliest cohort in the time series, that is, the major mode observed in January 1985 (FI = 0.221), it indicated that recruitment probably occurred in 1982. Since no other cohorts were represented in the FI frequency distributions until August 1986, it appears that relatively large recruitment episodes have occurred only three times since 1982.

Armorhead CPUE on each of the three Emperor Seamounts was 31.4 at Colahan, 7.1 at Kammu, and 14.3 at Koko, all considerably lower than on the Southeast Hancock Seamount (depth stratified mean, 147.0; nonstratified mean, 298.3). Although the sample sizes are small, the FI frequency distributions for Colahan and Kammu Seamounts both have had near the FI of recruiting fish (Fig. 18) and, like the Southeast Hancock Seamount, appeared to have received some recruitment during 1988. However, there was no indication that Koko Seamount received any recruitment. Koko Seamount was also anomalous in that the armorhead were considerably larger there than on the other seamounts (Fig. 18).

Discussion

Fishing has not occurred on the Southeast Hancock Seamount for 5 years, yet the population has not shown a sustained increase. There are at least two reasons for this. First, armorhead recruitment appears to to be quite variable not only in magnitude but also in frequency. Over the last 8 years, apparently only three recognizable recruitment episodes occurred, and in no case did the episodes follow each other in consecutive years. It is not clear if this sporadic pattern of recruitment is a usual feature of armorhead population dynamics or if it is related to the extremely low population level that currently exists. Its effect, however, is that even when relatively good recruitment does occur, as it did in 1986, a high population level does not persist for long because the natural mortality of armorhead is also high (ca. 50% per year).

A second reason why armorhead abundance has not shown a sustained increase is that the fish on the Southeast Hancock Seamount probably do not comprise a discrete spawning population and their progeny are equally likely to recruit to any of the Emperor or Hawaiian Ridge seamounts. The question of stock unity was examined in the last report (Somerton 1988), and there is no new evidence to contradict the hypothesis that all North Pacific armorhead belong to the same population. This is further supported by the apparent, recent recruitment to Colahan and Kammu Seamounts, which, based on the modal values of FI, appears to have occurred at the same time as the recruitment to the Southeast Hancock Seamount. Research on the population structure of armorhead is continuing, and during the 1988 exploratory cruise, tissue samples from several seamounts were collected and used for mitochondrial DNA analysis, a new technique for stock separation.

Although the Southeast Hancock Seamount population does not show a sustained increase, the moratorium on commercial fishing clearly provides some protection because the CPUE on the Southeast Hancock Seamount is 5-20 times higher than on the Emperor Seamounts. This difference in CPUE probably reflects a difference in fishing pressure between areas, but we are uncertain about the exact level of effort being expended on the Emperor Seamounts and only have fragmentary and anecdotal information. For example, during the 1988 survey, several foreign vessels (one Japanese, others probably Taiwanese) were observed on Kammu and Koko Seamounts, supposedly fishing alfonsin, <u>Beryx splendens</u>, with gill nets in deeper water. A brief conversation with the captain of one of these vessels revealed that the armorhead catch rates were so low that trawlers were no longer fishing the Emperor Seamounts. Regardless of the current level of fishing activity, various nations certainly have the capacity to fish the seamounts if it is profitable, and this would quickly reduce the population. Thus, the current fishing moratorium on the Hancock Seamounts appears to have preserved a brood stock, but this brood stock may be insufficient to allow significant population growth to occur either on the Southeast Hancock Seamount or the entire group of seamounts that once supported the fisheries. To change this situation, that some form of international management of the seamount resources clearly is needed.

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REFERENCES

Everson, A. R.
1984. Spawning and gonadal maturation of the ehu, _Etelis carbunculus_, in the Northwestern Hawaiian Islands. _In_ R. W. Grigg and K. Y. Tanoue (editors), Proceedings of the Second Symposium on Resource Investigations in the Northwestern Hawaiian Islands, Vol. 2, May 25-27, 1983, University of Hawaii, Honolulu, Hawaii, p. 128-148. UNIHI-SEAGRANT-MR-84-01.

Everson, A. R., H. A. Williams, and B. M. Ito.
In press. Maturation and reproduction in two Hawaiian eteline snappers: uku, _Aprion virescens_, and onaga, _Etelis coruscans_. Fish. Bull., U.S.

Kikkawa, B. S.
1984. Maturation, spawning, and fecundity of opakapaka, _Pristipomoides filamentosus_, in the Northwestern Hawaiian Islands. _In_ R. W. Grigg and K. Y. Tanoue (editors), Proceedings of the Second Symposium on Resource Investigations in the Northwestern Hawaiian Islands, Vol. 2, May 25-27, 1983, University of Hawaii, Honolulu, Hawaii, p. 149-160. UNIHI-SEAGRANT-MR-84-01.

Ralston, S.
1981. A study of the Hawaiian deep-sea handline fishery with special reference to the population dynamics of opakapaka, _Pristipomoides filamentosus_ (Pisces: Lutjanidae). Ph.D. Thesis, Univ. Wash., Seattle, WA, 204 p.

Ralston, S., and K. E. Kawamoto.
1987. An assessment and description of the status of bottom fish stocks in Hawaii. Southwest Fish. Cent. Honolulu Lab., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Cent. Admin. Rep. H-87-7, 55 p.

1988. A biological assessment of Hawaiian bottom fish stocks, 1984-87. Southwest Fish. Cent. Honolulu Lab., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Cent. Admin. Rep. H-88-8, 60 p.

Ralston, S., D. T. Tagami, and P. M. Shiota.
1986. An analysis of bottom fish size variation at the Honolulu fish auction. Southwest Fish. Cent. Honolulu Lab., Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Cent. Admin. Rep. H-86-10, 11 p.

Somerton, D. A.
1988. Assessment of the stock condition of pelagic armorhead on Southeast Hancock Seamount. Southwest Fish. Cent. Honolulu Lab. Natl. Mar. Fish. Serv., NOAA, Honolulu, HI 96822-2396. Southwest Fish. Cent. Admin. Rep. H-88-9, 7 p.

Somerton, D. A.
In prep. A method of stock assessment using time-to-capture of individual fish on a longline and its application to pelagic armorhead, Pseudopentaceros wheeleri, on the Hancock Seamount.

Somerton, D. A., and B. S. Kikkawa.
In prep. Contribution to the life history of pelagic armorhead, Pseudopentaceros wheeleri, on the Southeast Hancock Seamount.

Somerton, D. A., B. S. Kikkawa, and C. D. Wilson.
1988. Hook timers to measure the capture time of individual fish. Mar. Fish. Rev. 50(2):1-5.

Sudekum, A. E., J. D. Parrish, R. L. Radtke, and S. Ralston.
In prep. Life history and trophic ecology of two large jacks in the Northwestern Hawaiian Islands. Hawaii Coop. Fish. Res. Unit, Univ. Hawaii, Honolulu, HI 96822.

Western Pacific Regional Fishery Management Council.
1986. Combined fishery management plan, environmental assessment and regulatory impact review for the bottom fish and seamount groundfish fisheries of the western Pacific region. Western Pacific Regional Fishery Management Council, 1164 Bishop Street, Honolulu, HI 96813-2586, var. pag.

Table 1.--Common and scientific names of Hawaiian bottom fishes.

Common name	Scientific name
Lehi	*Aphareus rutilans*
Uku	*Aprion virescens*
Ehu	*Etelis carbunculus*
Onaga	*Etelis coruscans*
Opakapaka	*Pristipomoides filamentosus*
Kalekale	*Pristipomoides sieboldii*
Gindai	*Pristipomoides zonatus*
Hapuupuu	*Epinephelus quernus*
White ulua	*Caranx ignobilis*
Butaguchi	*Pseudocaranx dentex*

Table 2.--Landings of principal bottom fish species from the main Hawaiian Islands (MHI) and Northwestern Hawaiian Islands (NWHI), 1984-88.

Species	Region	Catch (metric tons) 1984	1985	1986	1987	1988
Lehi	MHI	5.4	7.4	4.8	10.3	20.2
	NWHI	0.01	0.0	0.0	0.0	0.03
Uku	MHI	62.2	16.2	41.8	25.0	281.8
	NWHI	3.4	0.7	3.1	1.6	3.5
Ehu	MHI	13.0	25.8	23.8	30.2	21.2
	NWHI	2.2	9.3	12.5	18.0	20.3
Onaga	MHI	73.4	128.6	116.2	144.7	102.7
	NWHI	3.1	23.3	43.6	28.9	36.3
Opakapaka	MHI	75.0	61.8	73.0	138.0	215.3
	NWHI	143.4	140.5	122.6	165.3	69.5
Kalekale	MHI	8.8	13.8	11.2	18.2	8.2
	NWHI	1.3	2.9	2.8	1.9	1.0
Gindai	MHI	1.2	1.6	1.8	1.2	2.2
	NWHI	1.3	2.7	3.4	3.8	1.6
Hapuupuu	MHI	13.4	6.8	7.2	9.1	11.5
	NWHI	46.1	66.8	86.6	99.8	70.3
White ulua	MHI	17.4	14.4	13.8	9.1	37.7
	NWHI	12.0	27.7	13.4	25.3	27.5
Butaguchi	MHI	1.6	0.8	1.2	2.9	7.9
	NWHI	29.5	56.2	66.1	97.0	50.0
Total	MHI	271.6	277.2	295.0	389.6	707.6
	NWHI	242.4	330.1	354.1	441.6	280.0
Total		514.0	607.3	649.1	831.2	987.6

Table 3.--Effective effort (number of 1,000-lb trips) and catch per unit effort (CPUE × 1,000) (pounds of bottom fish per trip) for the bottom fish fishery in the Northwestern Hawaiian Islands 1984-88.

	1984		1985		1986		1987		1988	
Vessel	Trips	CPUE	Trips	CPUE	Trips	CPUE	Trips	CPUE	Trips	CPUE
A	2	6.1	--	--	--	--	--	--	--	--
B	1	1.0	--	--	--	--	--	--	--	--
C	7	2.6	--	--	--	--	--	--	--	--
D	10	10.6	--	--	--	--	1	--	--	--
E	2	2.7	--	--	--	--	1	2.3	--	--
F	4	1.3	1	2.1	--	--	--	--	--	--
G	4	3.4	3	4.1	--	--	--	--	--	--
H	8	4.0	6	3.2	--	--	--	--	--	--
I	3	1.8	4	1.6	1	1.2	--	--	--	--
J	5	4.0	11	4.3	8	4.3	11	5.6	9	4.6
K	12	8.4	13	8.2	11	6.1	4	7.2	--	--
L	12	4.7	5	3.5	2	3.4	3	4.3	3	2.0
M	6	5.1	10	5.6	8	3.3	7	4.8	--	--
N	3	4.5	3	3.0	4	5.0	5	5.2	--	--
O	10	3.1	15	4.2	11	4.0	11	5.8	14	5.1
P	5	3.7	4	3.3	13	4.7	3	7.5	--	--
Q	4	3.2	16	5.8	15	5.5	16	9.4	13	8.0
R	9	3.6	5	3.2	8	6.3	6	5.0	3	4.8
S	--	--	4	6.9	5	7.3	3	9.8	--	--
T	--	--	1	3.3	9	8.3	6	13.6	7	8.6
U	--	--	1	4.0	3	1.2	2	5.3	--	--
V	--	--	1	2.3	2	1.2	3	6.9	--	--
W	--	--	11	8.8	11	11.1	11	12.0	7	16.7
X	--	--	13	7.3	7	6.1	2	6.7	1	4.7
Y	--	--	6	1.6	6	1.9	--	--	--	--
Z	--	--	1	5.5	--	--	1	4.5	--	--
AA	--	--	--	--	3	11.1	3	14.3	--	--
BB	--	--	--	--	1	1.2	2	3.6	--	--
CC	--	--	--	--	3	3.7	2	5.9	--	--
DD	--	--	--	--	7	1.5	2	1.6	9	2.1
EE	--	--	--	--	1	6.5	--	--	--	--
FF	--	--	--	--	--	--	3	3.4	--	--
GG	--	--	--	--	--	--	3	1.7	6	3.3
HH	--	--	--	--	--	--	3	3.0	--	--
II	--	--	--	--	--	--	4	5.5	--	--
JJ	--	--	--	--	--	--	--	--	2	2.1
KK	--	--	--	--	--	--	--	--	1	1.9
LL	--	--	--	--	--	--	--	--	5	5.4
MM	--	--	--	--	--	--	--	--	3	2.4
Average catch/ trip	--	4.8	--	5.3	--	5.4	--	7.1	--	6.0
Total	107	--	134	--	139	--	118	--	83	--

Table 4.--Inclusive dates and sample sizes, expressed as number of longline hooks set, for the eight stock assessment cruises to Southeast (SE) Hancock Seamount and the one research cruise to the Emperor Seamounts.

Date	Area	Hooks
2-26 February 1985	SE Hancock	2,016
20 June-15 July 1985	SE Hancock	2,718
11 August-8 September 1986	SE Hancock	6,711
31 October-11 November 1986	SE Hancock	2,948
12-27 March 1987	SE Hancock	3,636
16-24 August 1987	SE Hancock	4,534
13-29 January 1988	SE Hancock	3,538
13-25 July 1988	SE Hancock	4,185
31 July-21 August 1988	Colahan	1,562
	Kammu	3,109
	Koko	5,482
	SE Hancock	2,319

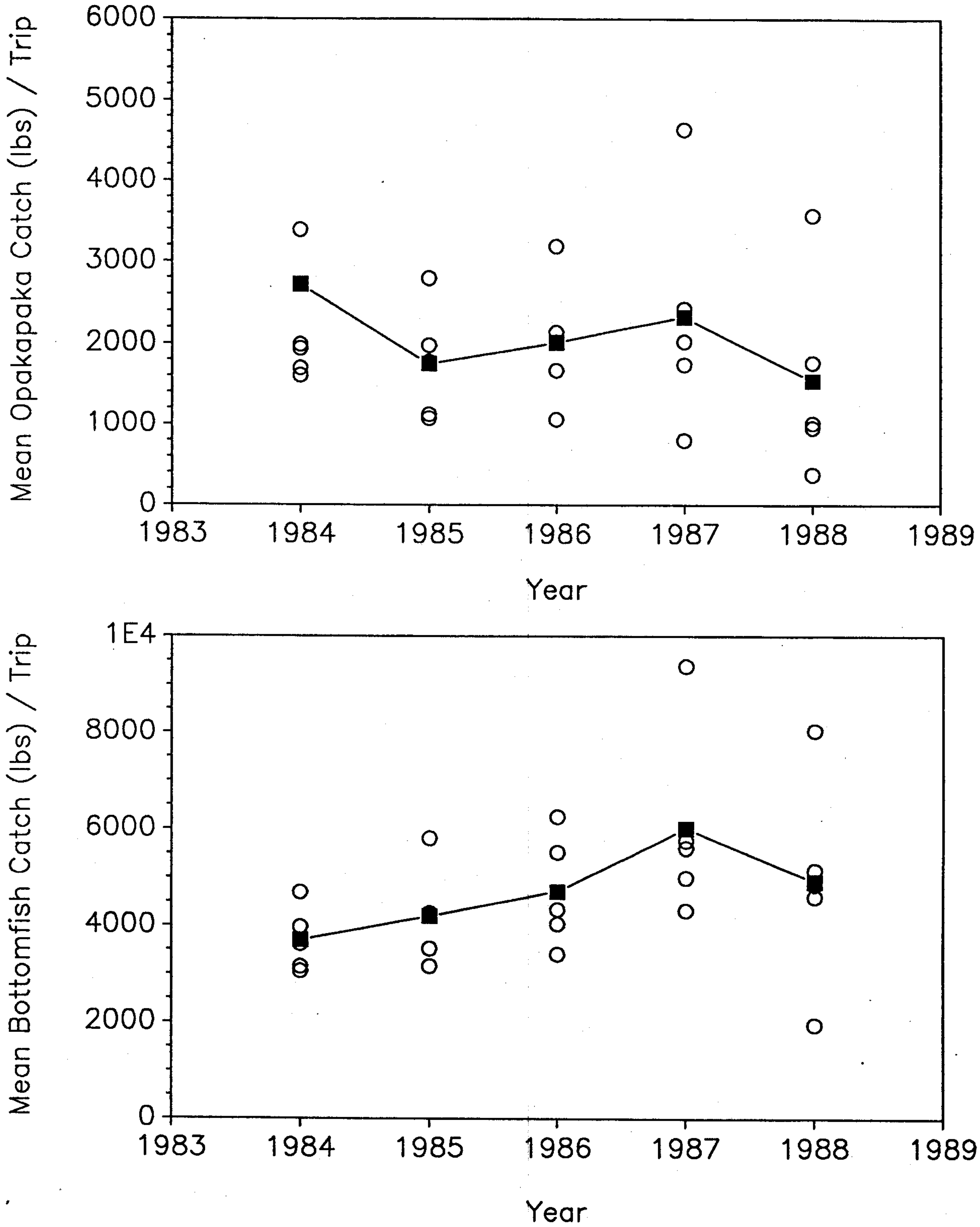


Figure 1.--Catch rate statistics for opakapaka (top) above and bottom fish (bottom) for the five vessels active in the Northwestern Hawaiian Islands during the 1984-88 period. Open circles are annual mean catch rates for individual vessels; closed squares are the yearly group means.

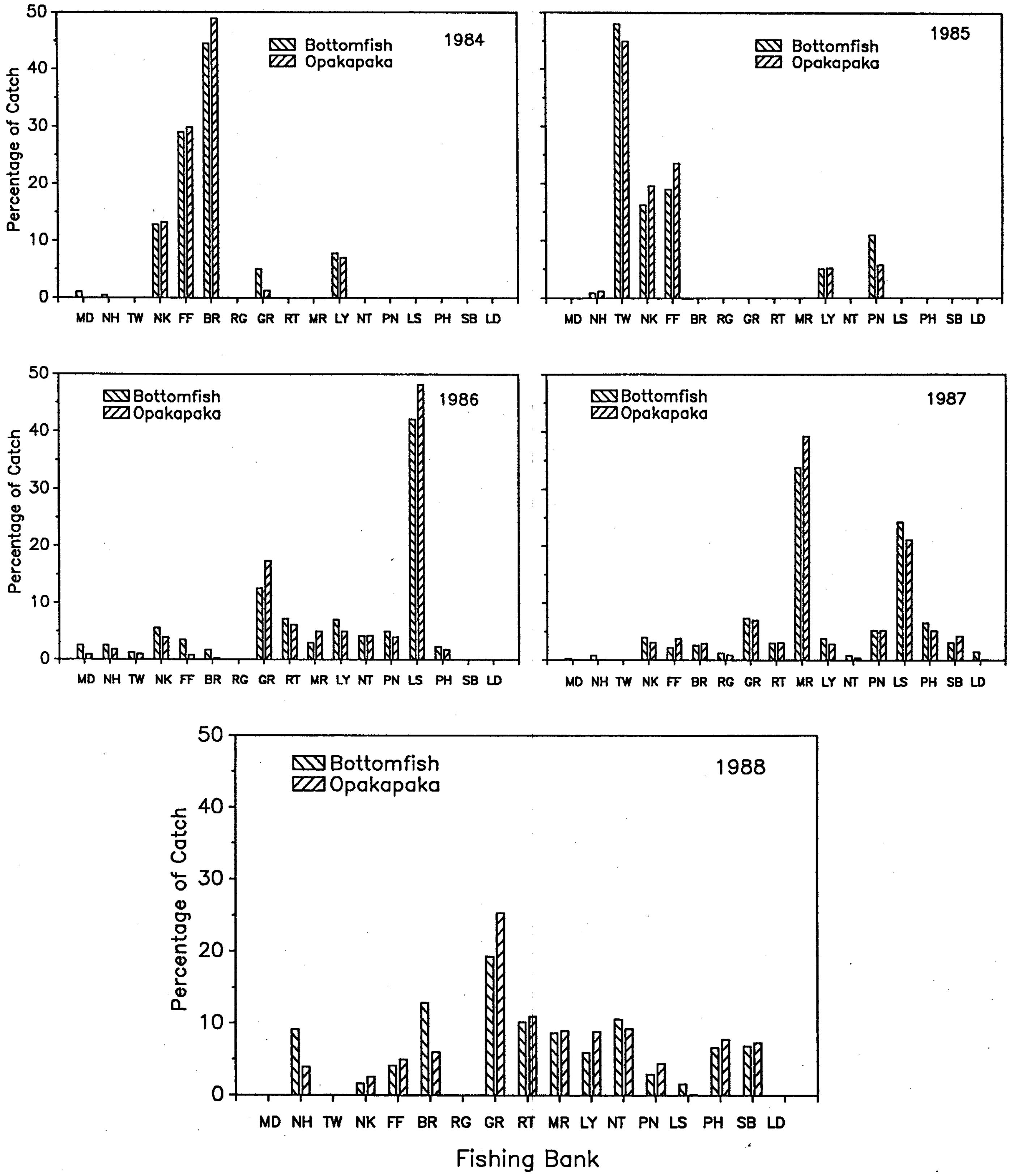


Figure 2.--Locations of bottom fish and opakapaka harvests in the Northwestern Hawaiian Islands, 1984-88: MD = Middle Bank, NH = Nihoa, TW = Twin Banks, NK = Necker Island, FF = French Frigate Shoals, BR = Brooks Banks, RG = St. Rogatien Bank, GR = Gardner Pinnacles, RT = Raita Bank, MR = Maro Reef, LY = Laysan Island, NT = Northampton Seamount, PN = Pioneer Bank, LS = Lisianski Island, PH = Pearl and Hermes Reef, SB = Salmon Bank, and LD = Ladd Seamount.

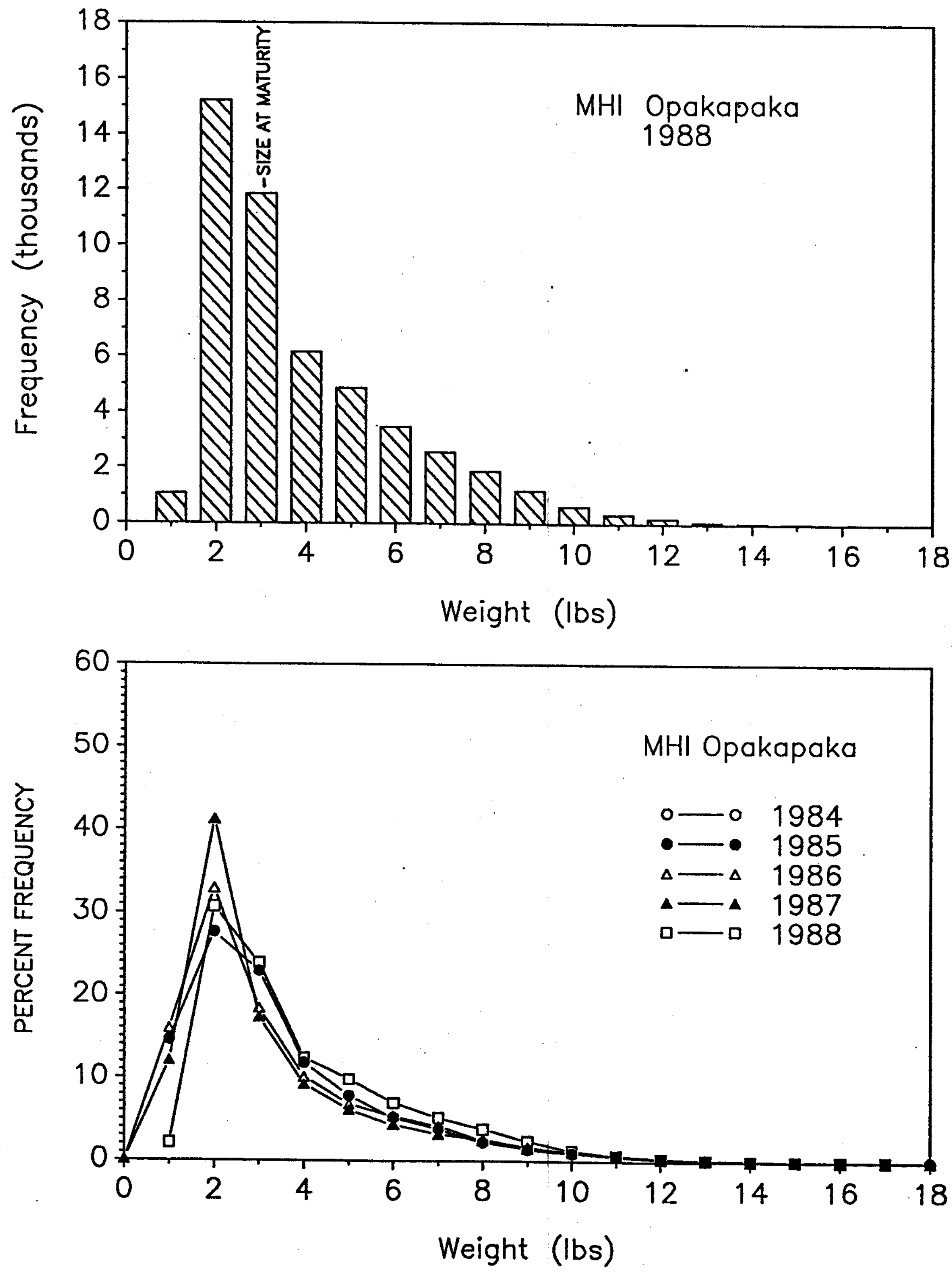


Figure 3.--Weight-frequency distributions of main Hawaiian Islands (MHI) opakapaka based upon market samples in 1988 (top) and in 1984-88 (bottom).

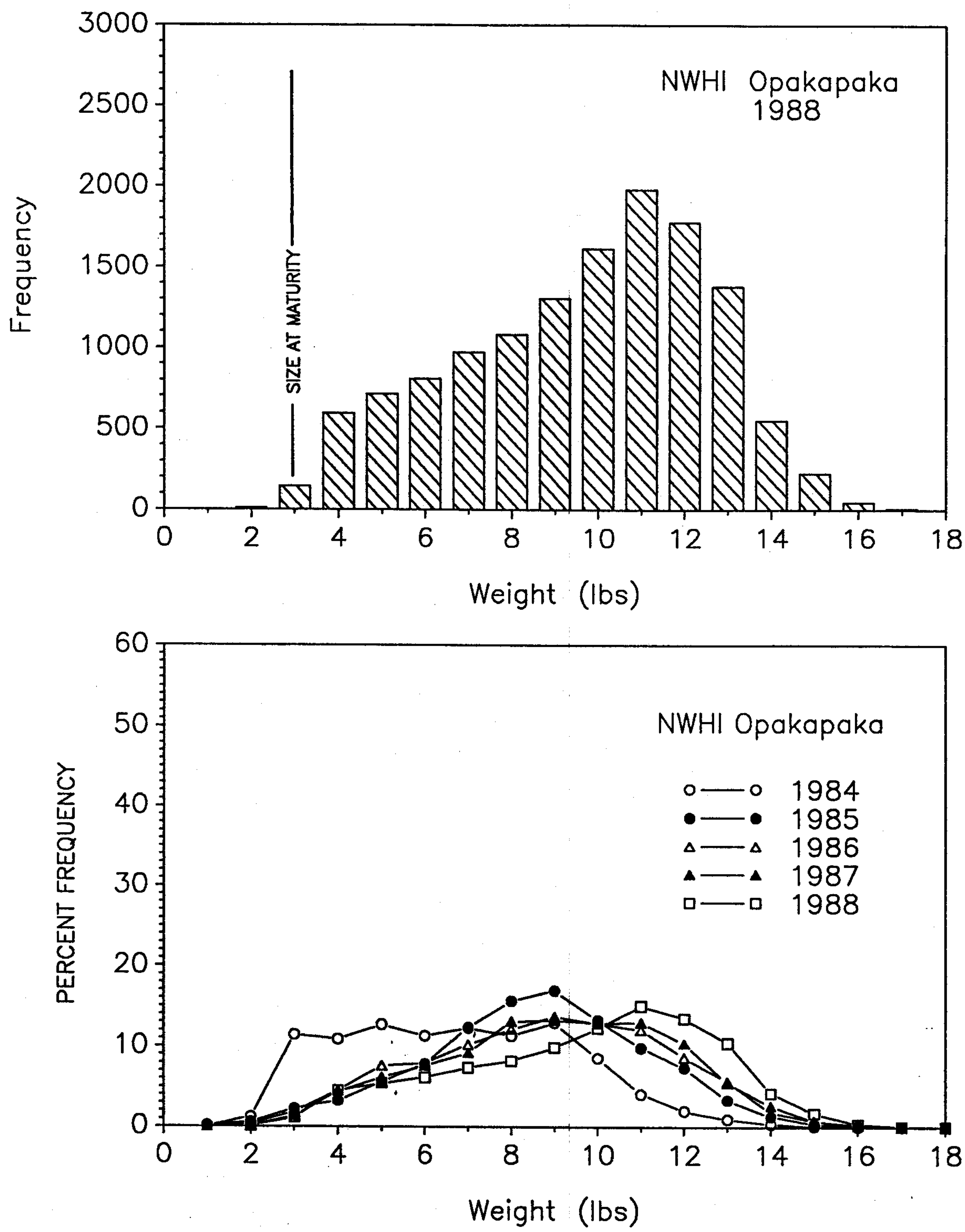


Figure 4.--Weight-frequency distributions of Northwestern Hawaiian Islands (NWHI) opakapaka based upon market samples in 1988 (top) and in 1984-88 (bottom).

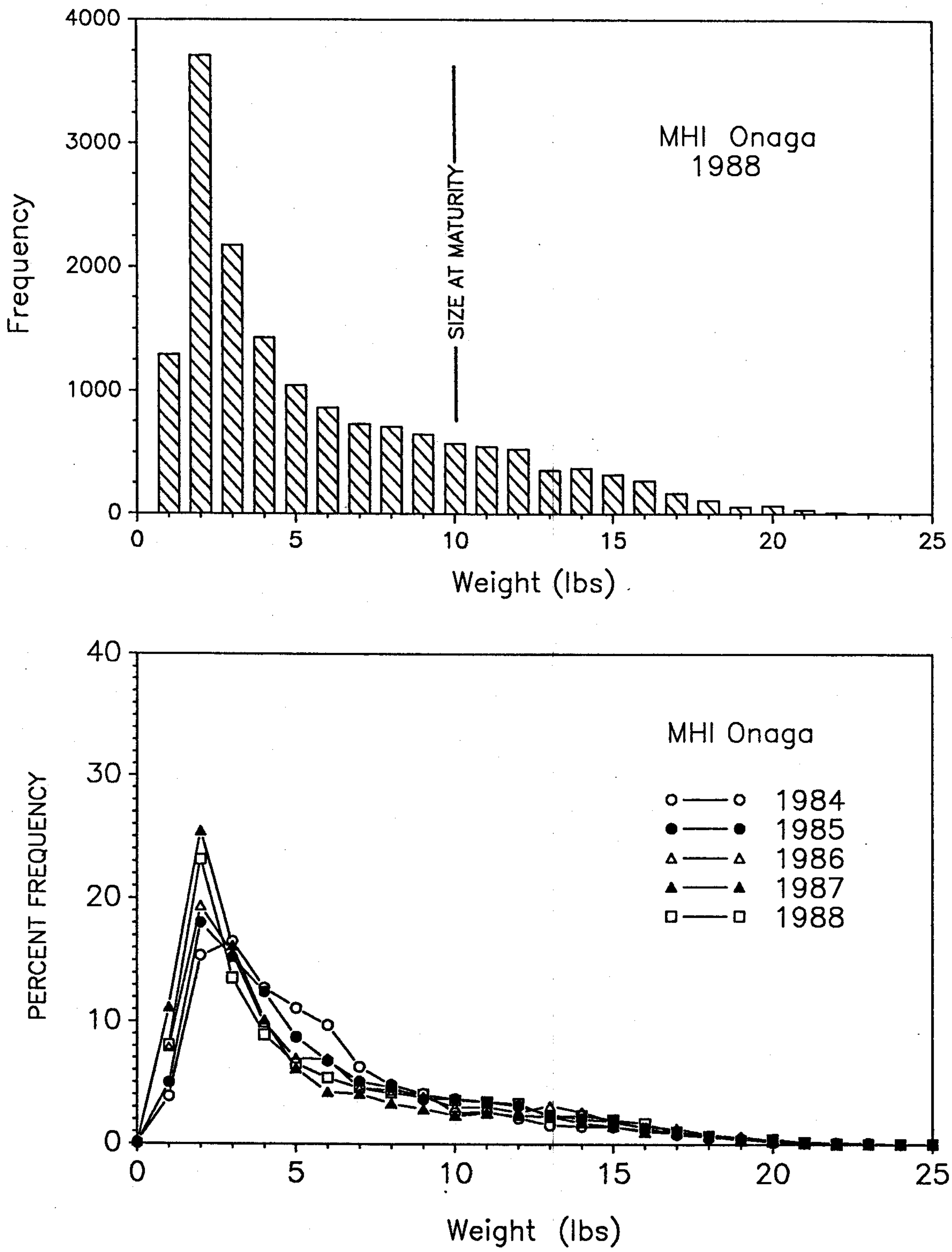


Figure 5.--Weight-frequency distributions of main Hawaiian Islands (MHI) onaga based upon 1988 market samples (top) and descending limbs of estimated relative length-frequency distributions in 1984-88 (bottom).

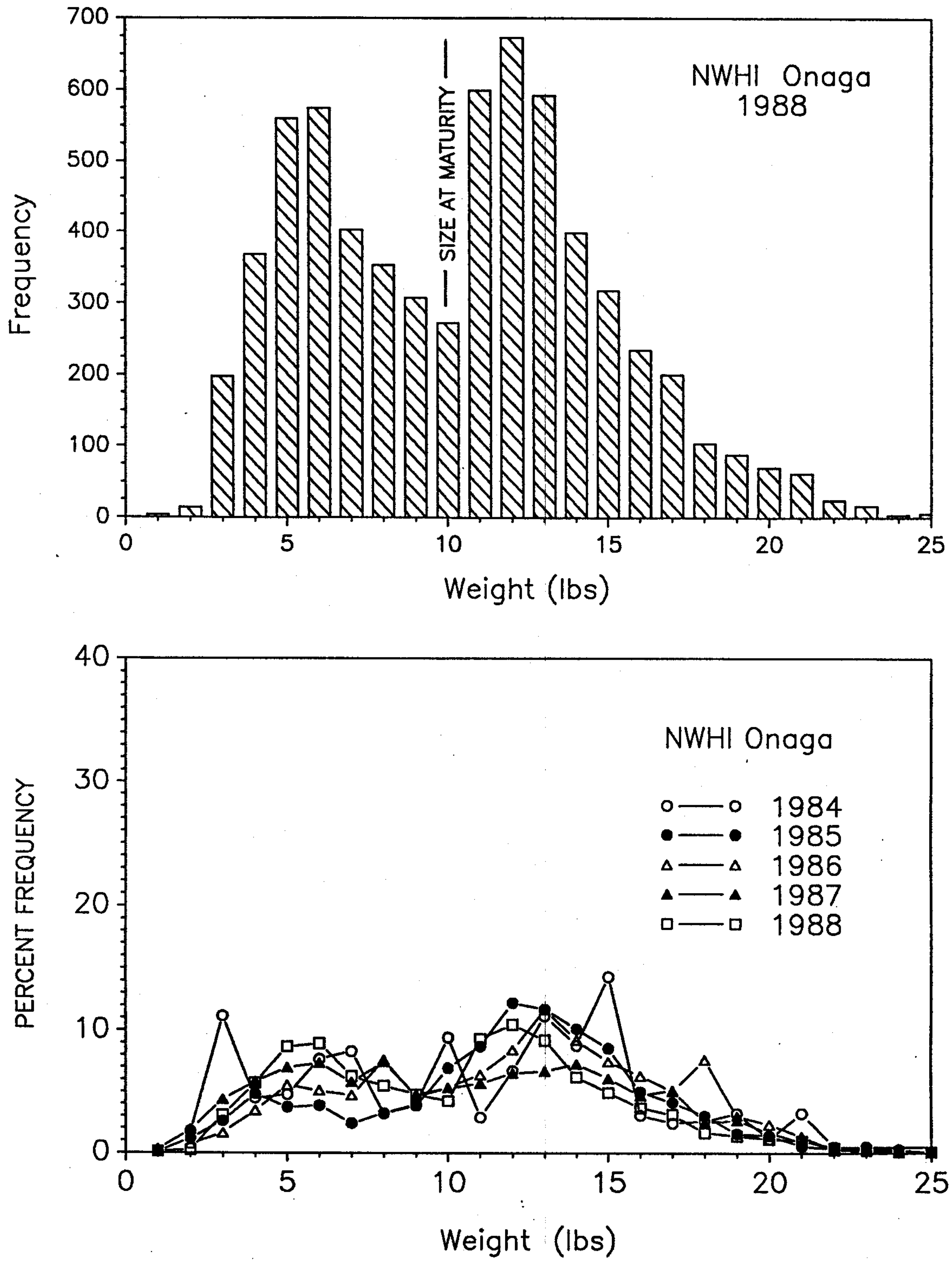


Figure 6.--Weight-frequency distributions of Northwestern Hawaiian Islands (NWHI) onaga based upon market samples in 1988 (top) and in 1984-88 (bottom).

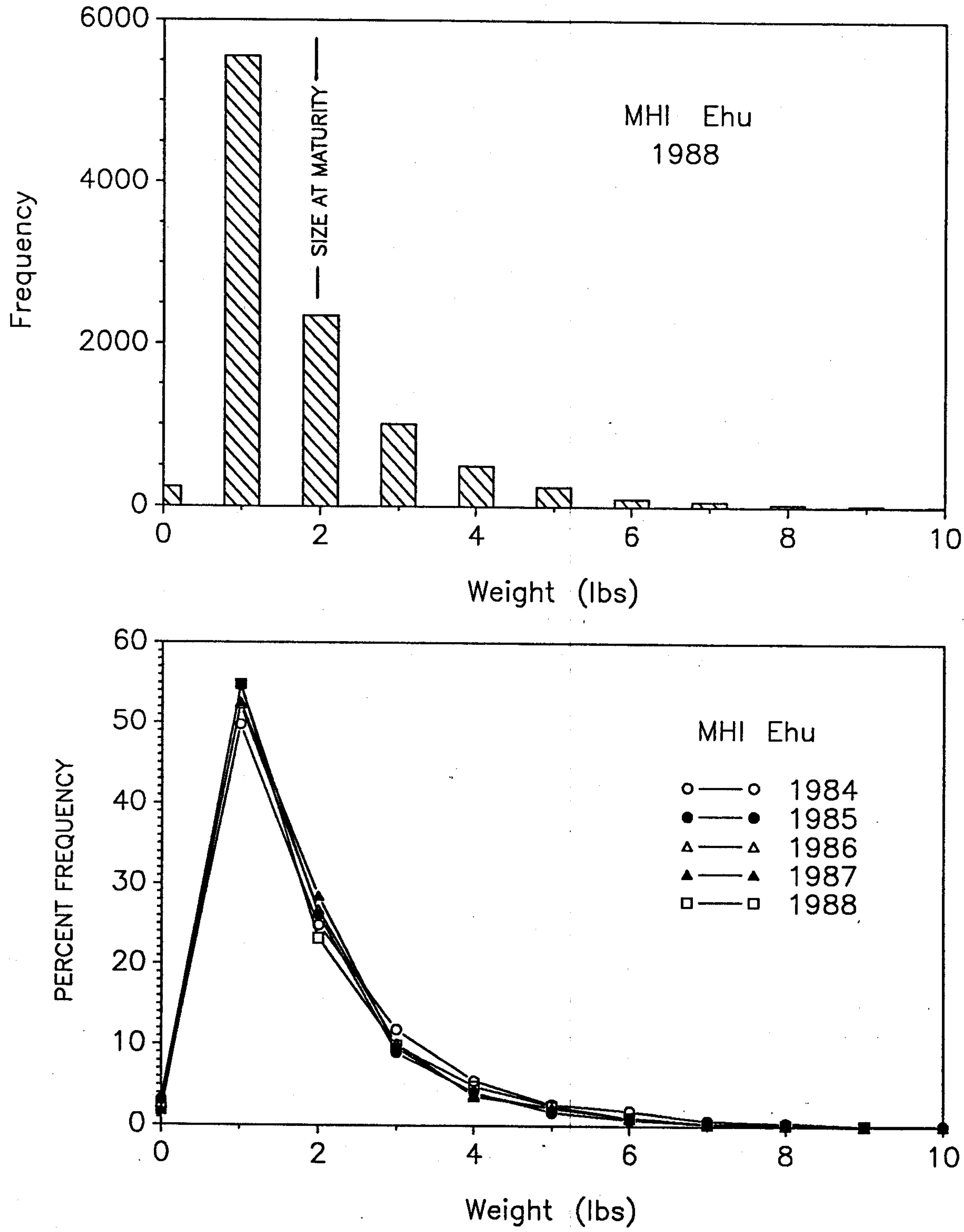
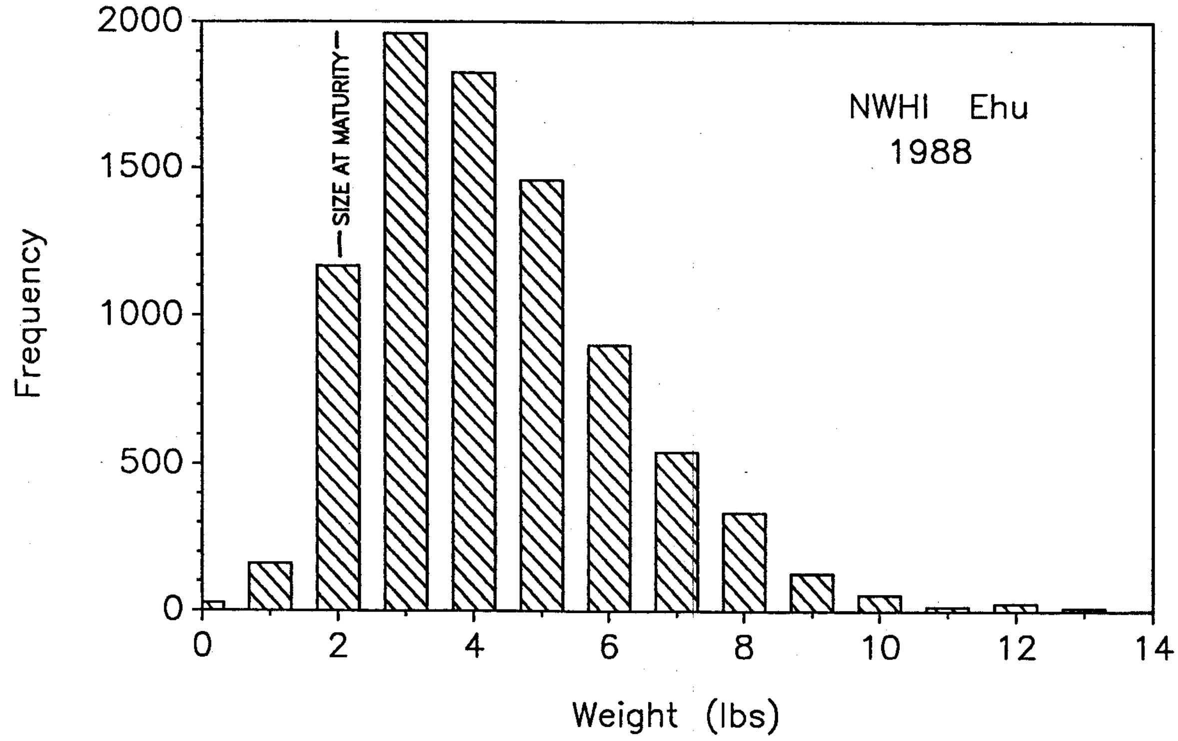


Figure 7.--Weight-frequency distributions of main Hawaiian Islands (MHI) ehu based upon market samples in 1988 (top) and in 1984-88 (bottom).



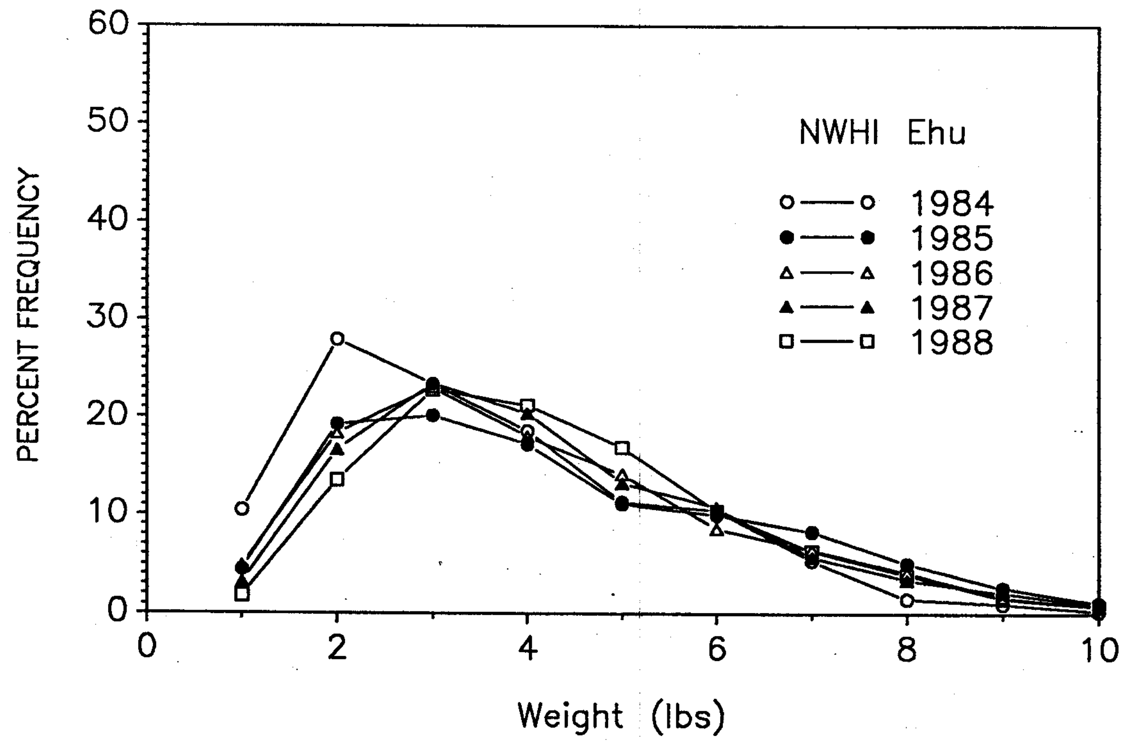
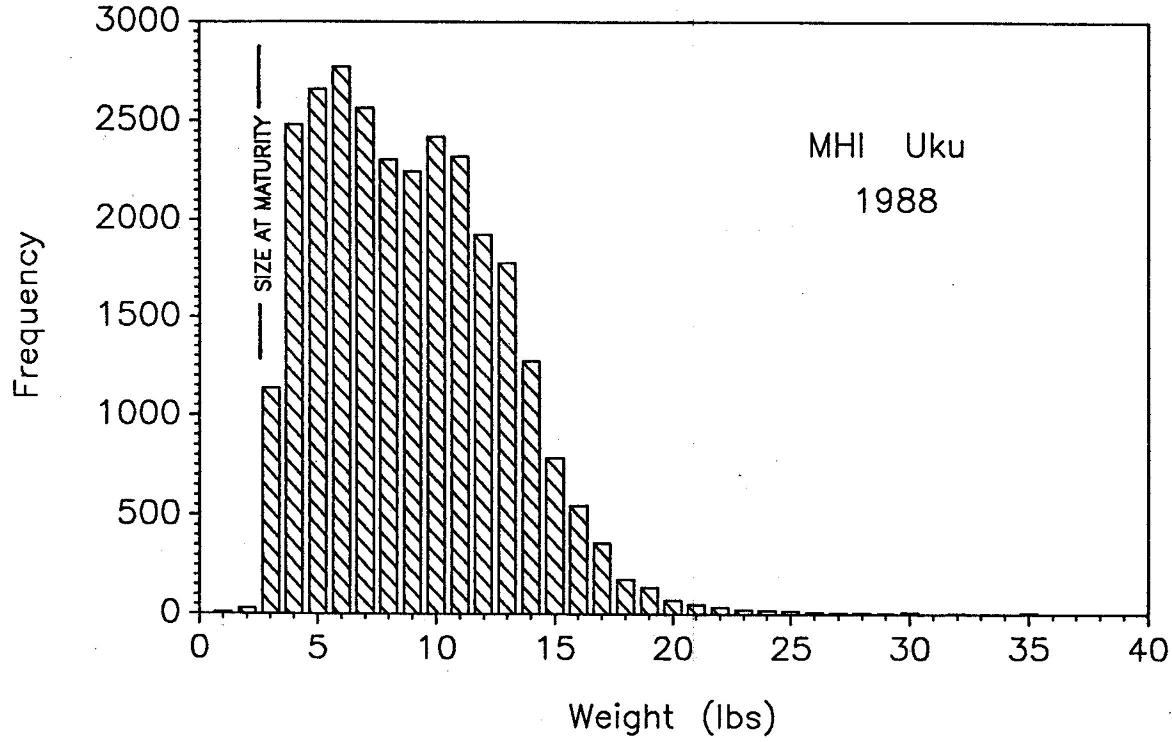


Figure 8.--Weight-frequency distributions of Northwestern Hawaiian Islands (NWHI) ehu based upon market samples in 1988 (top) and in 1984-88 (bottom).



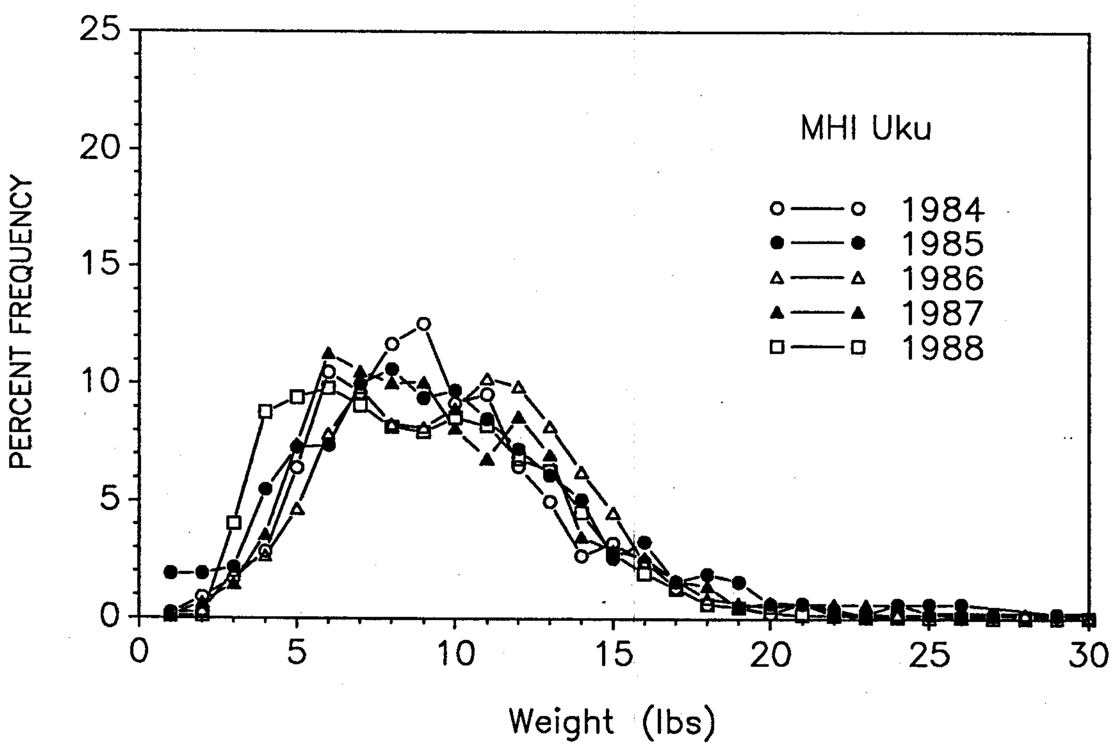


Figure 9.--Weight-frequency distributions of main Hawaiian Islands (MHI) uku based upon market samples in 1988 (top) and in 1984-88 (bottom).

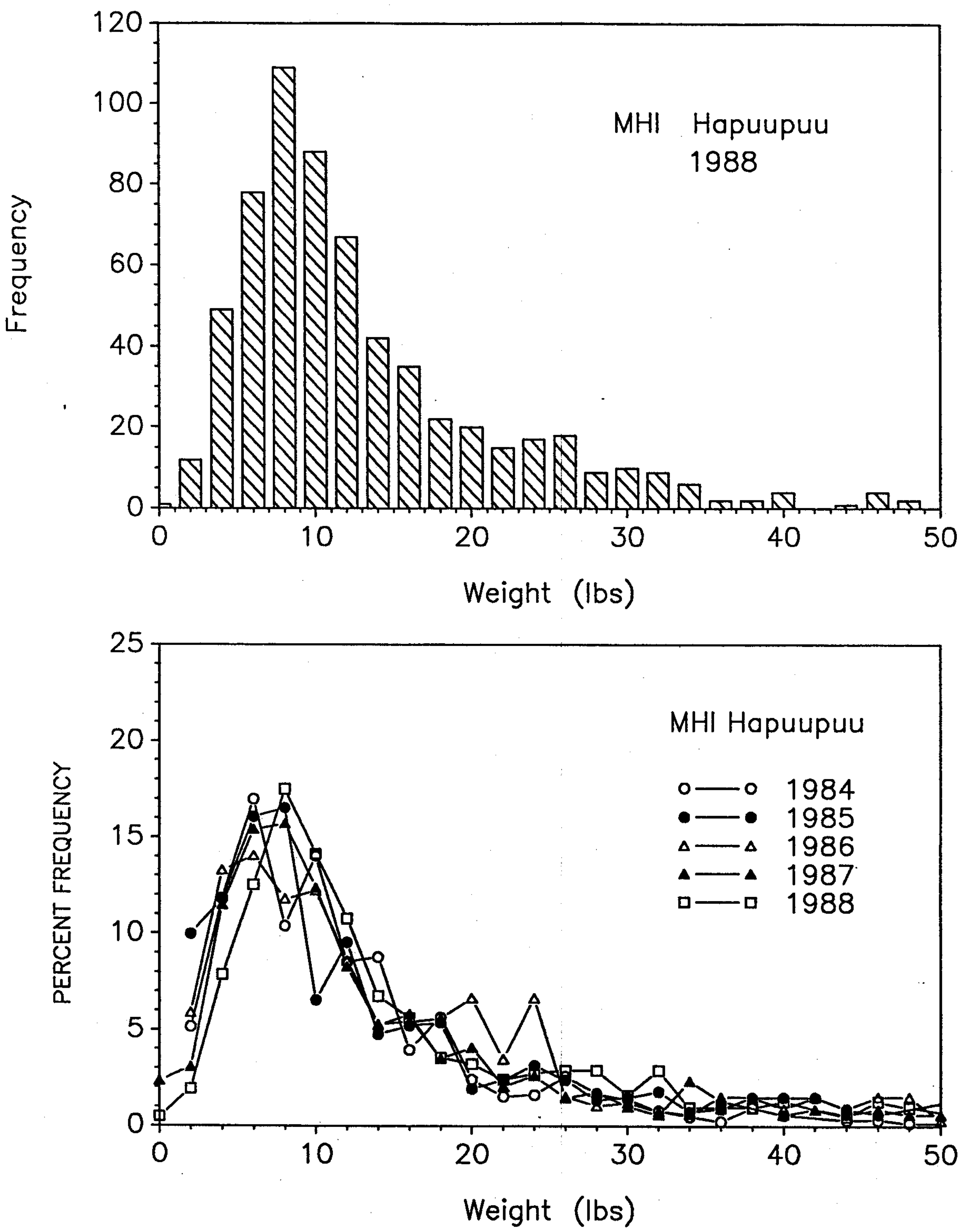


Figure 10.--Weight-frequency distributions of main Hawaiian Islands (MHI) hapuupuu based upon market samples in 1988 (top) and in 1984-88 (bottom).

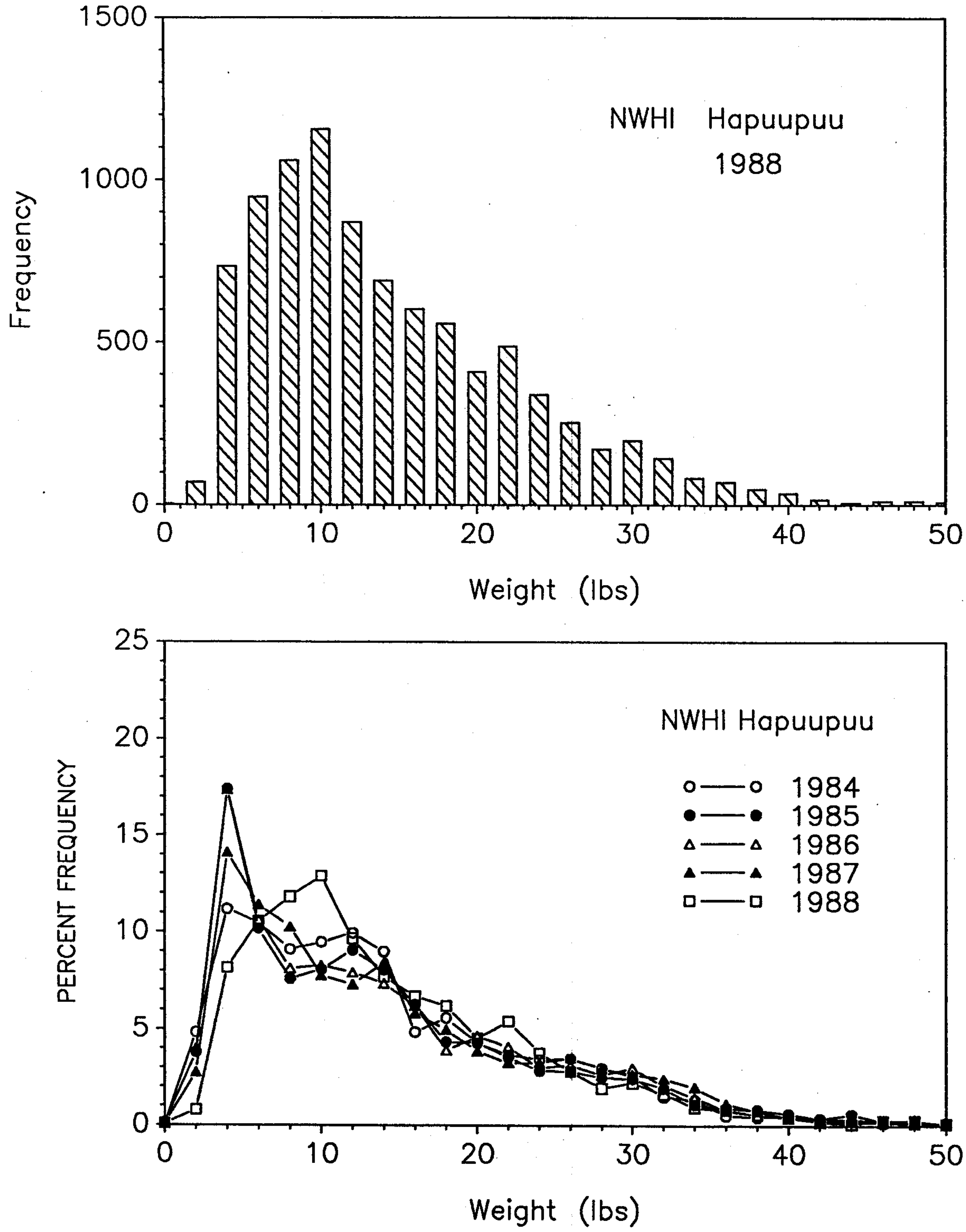


Figure 11.--Weight-frequency distributions of Northwestern Hawaiian Islands (NWHI) hapuupuu based upon market samples in 1988 (top) and in 1984-88 (bottom).

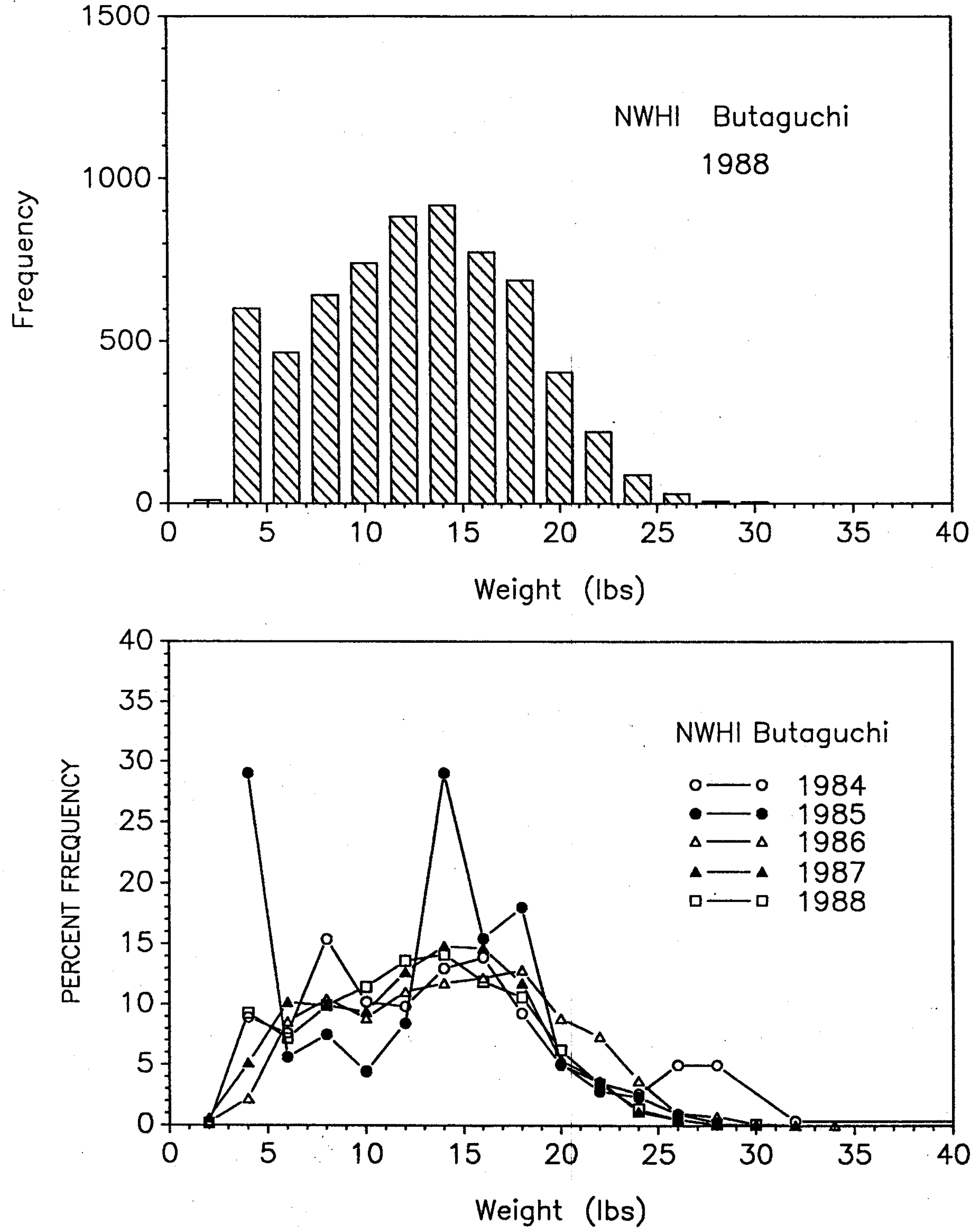
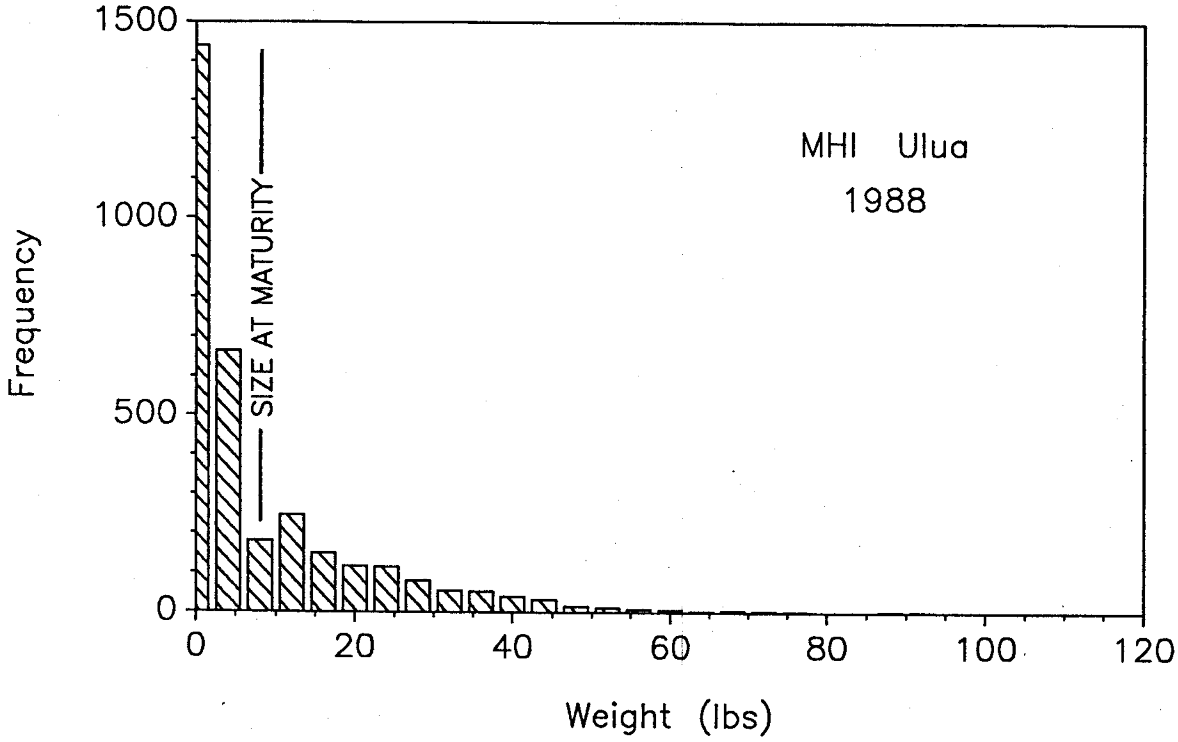


Figure 12.--Weight-frequency distributions of Northwestern Hawaiian Islands (NWHI) butaguchi based upon market samples in 1988 (top) and in 1984-88 (bottom).



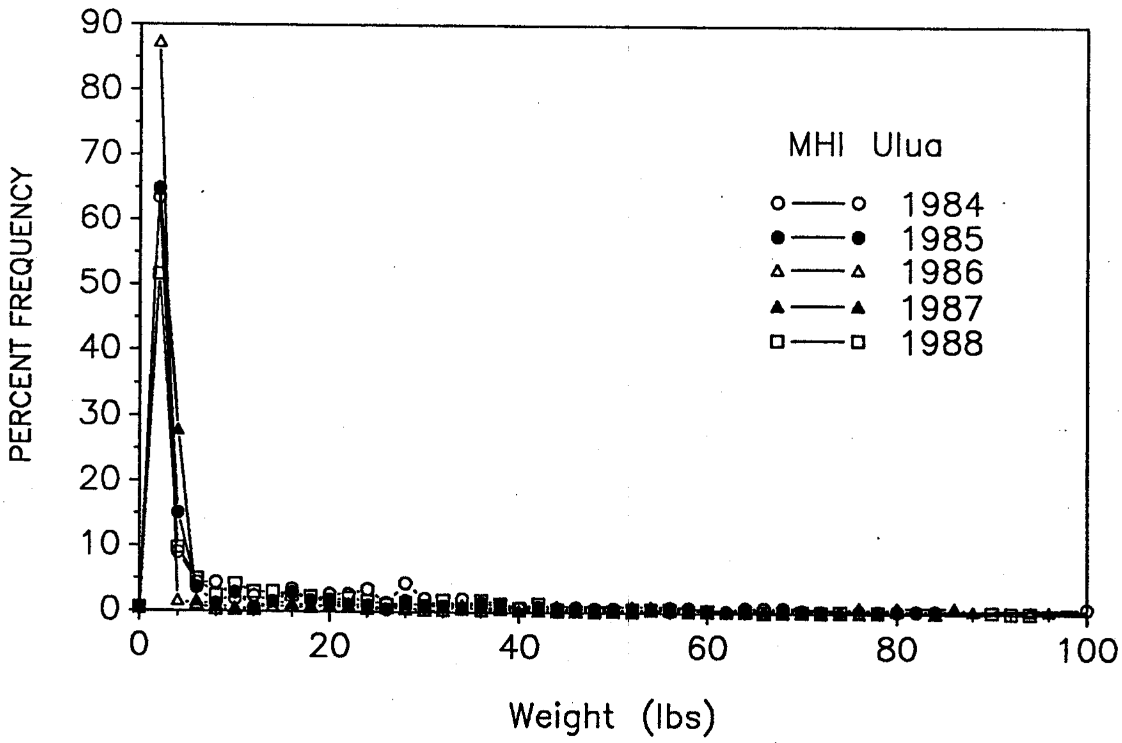


Figure 13.--Weight-frequency distributions of main Hawaiian Islands (MHI) white ulua based upon market samples in 1988 (top) and in 1984-88 (bottom).

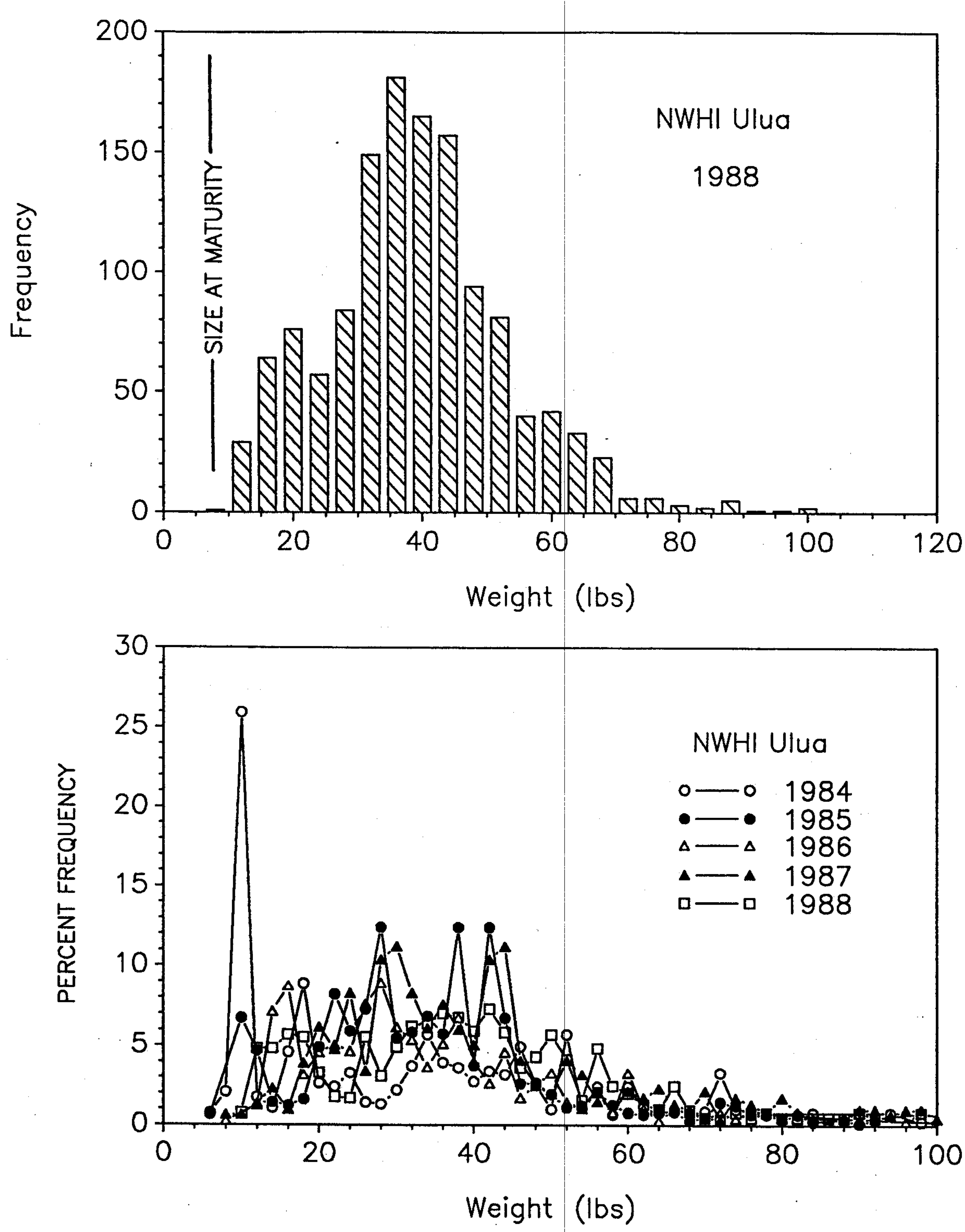


Figure 14.--Weight-frequency distributions of Northwestern Hawaiian Islands (NWHI) white ulua based upon market samples in 1988 (top) and in 1984-88 (bottom).

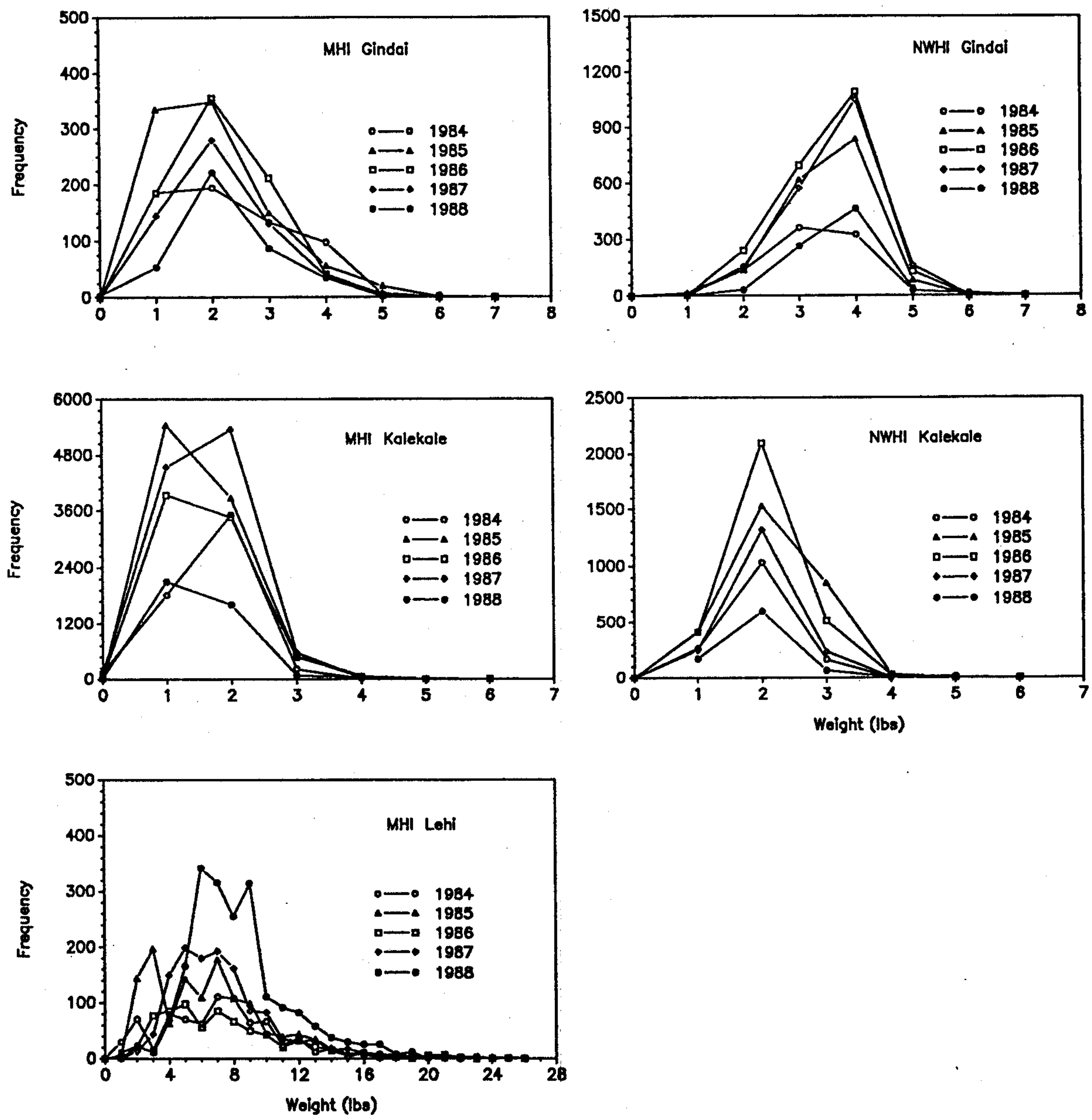


Figure 15.--Weight-frequency distributions gindai and kalekale for the main Hawaiian Islands (MHI) and Northwestern Hawaiian Islands (NWHI) and for lehi from the MHI.

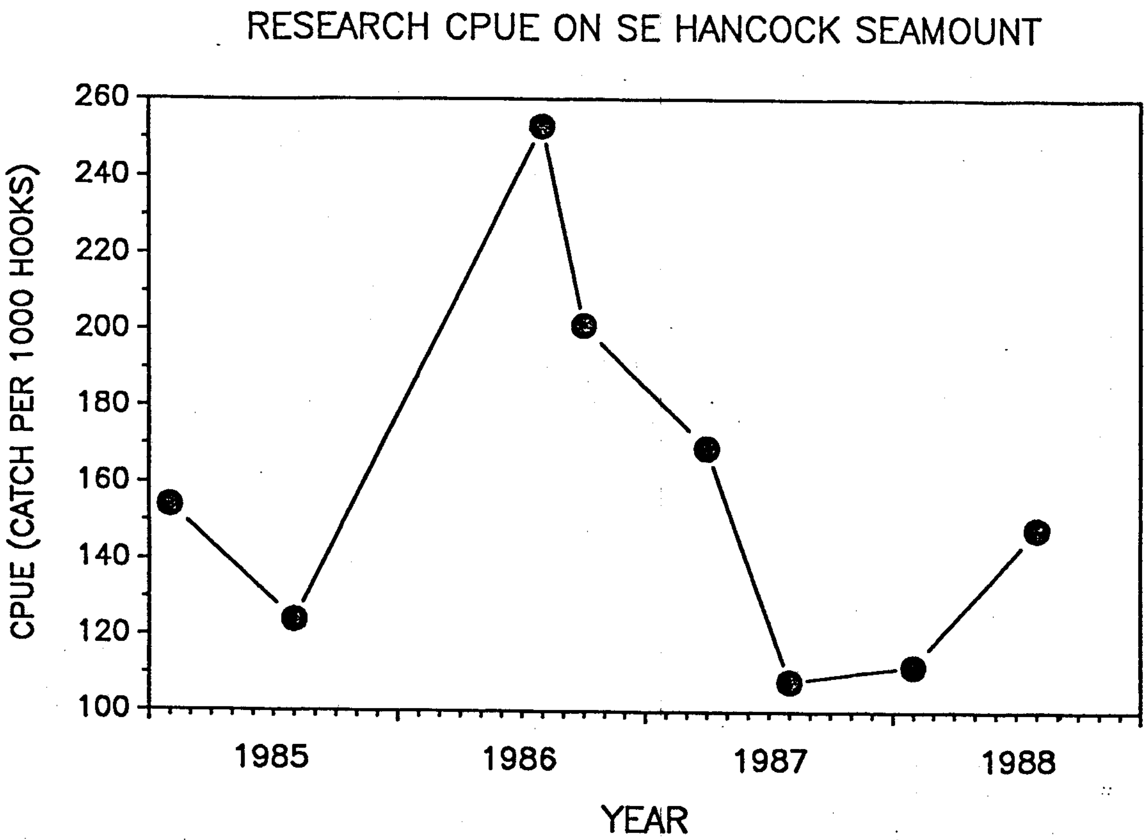


Figure 16.--Research longline catch per hook on the Southeast Hancock Seamount for eight stock assessment cruises in 1985-88.

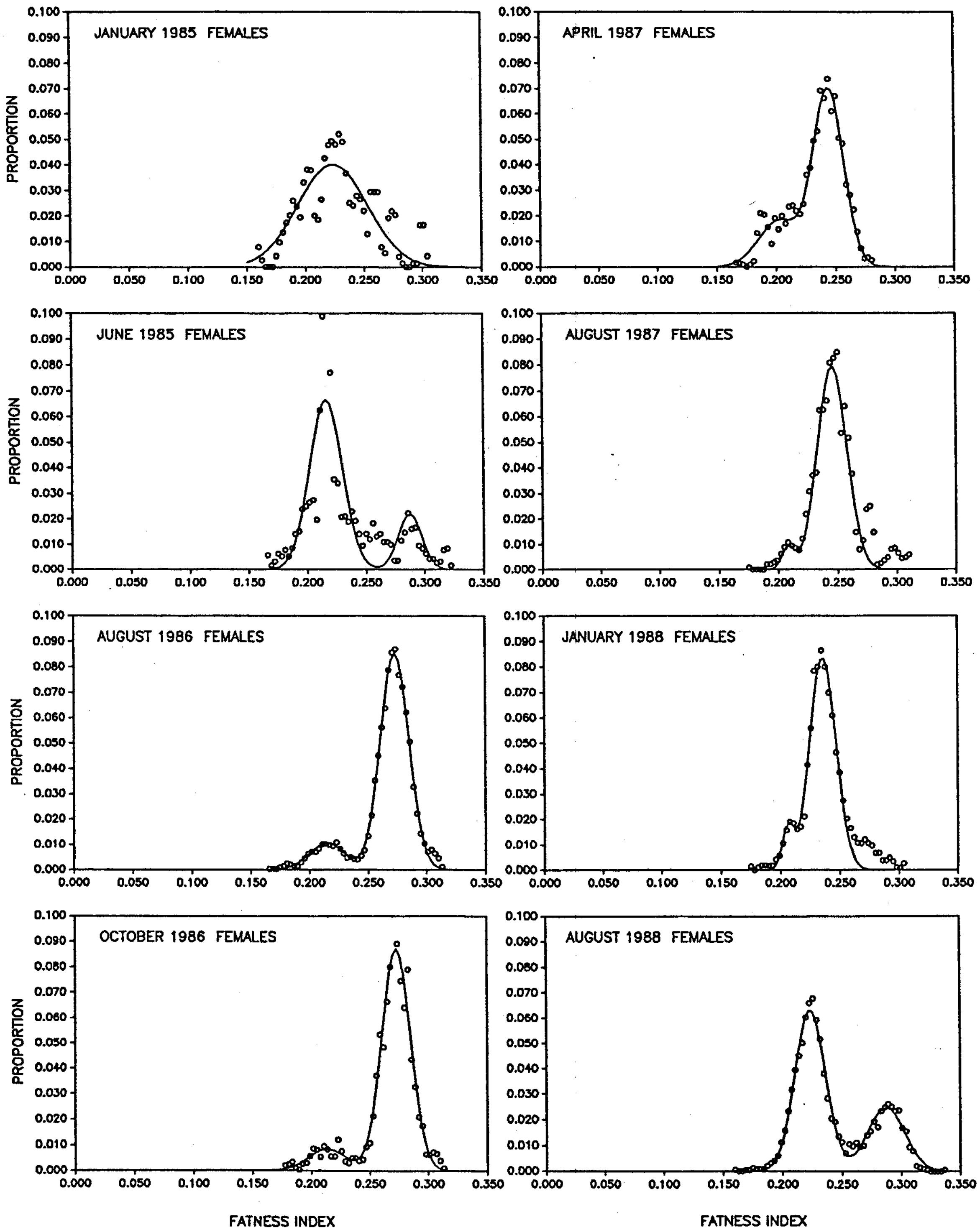


Figure 17.--Frequency histograms of fatness index for female armorhead sampled during eight stock assessment cruises in 1985-88. A line delineating the composite fatness distribution of two recruitment cohorts is also shown for each cruise. This line is used to statistically define the groups and is described more fully in Somerton and Kikkawa (in prep.).

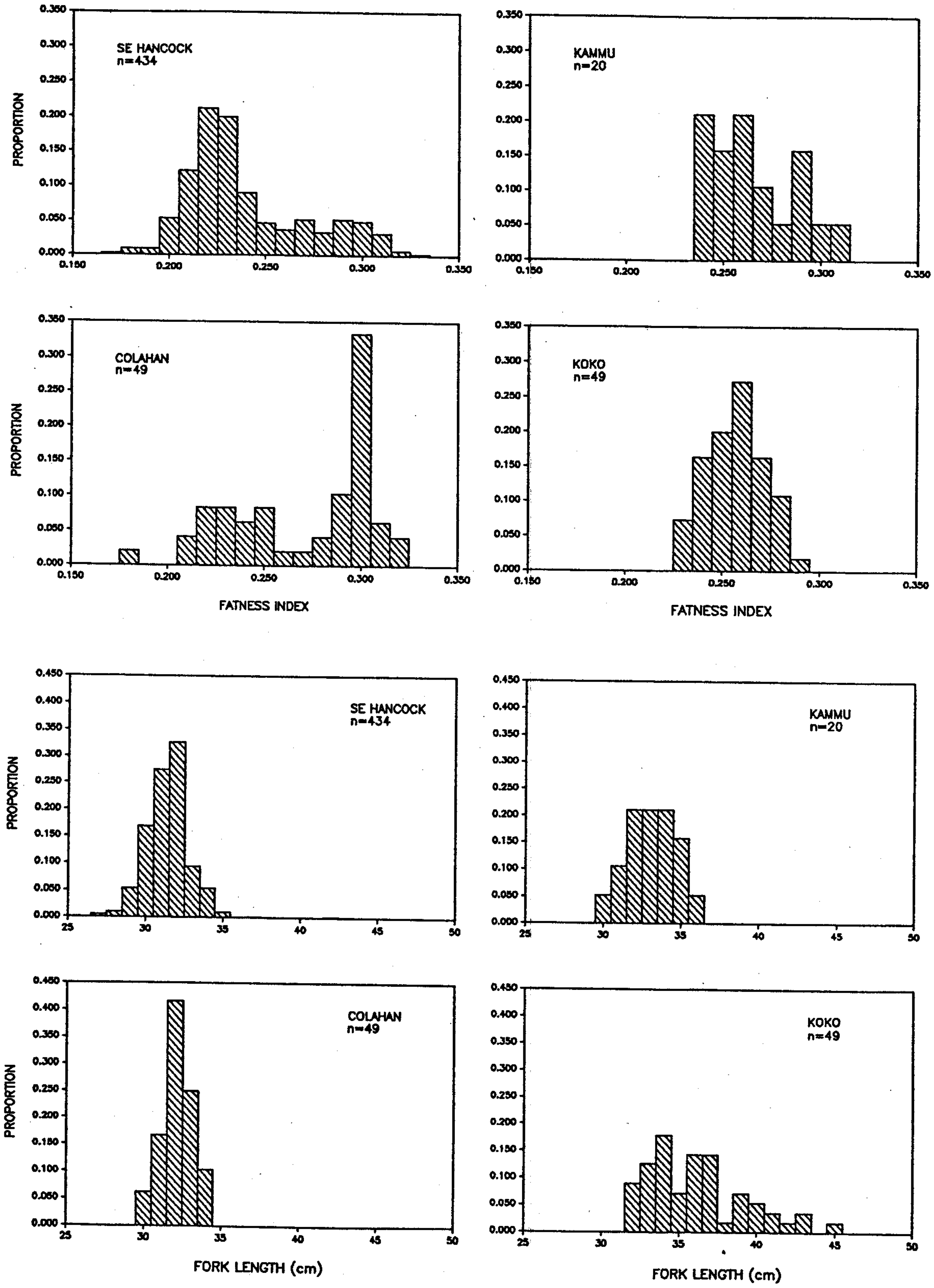


Figure 18.--Frequency histograms of fatness index and fork length (both sexes combined) for the Southeast Hancock, Colahan, Kammu, and Koko Seamounts.